STRATIGRAPHY OF THE COAL FIELDS OF NORTHERN CENTRAL NEW MEXICO

DISSERTATION

Submitted to the Board of University Studies of the Johns Hopkins University in Conformity with the Requirements for the Degree of

DOCTOR OF PHILOSOPHY

BY

WILLIS THOMAS LEE

BALTIMORE
1913

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STRATIGRAPHY OF THE COAL FIELDS OF NORTHERN CENTRAL NEW MEXICO[1]

BY WILLIS T. LEE

(*Presented before the Society December 27, 1911*)

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LOCATION OF AREAS EXAMINED

The areas in which the observations forming the basis of this paper were made lie in central and northern New Mexico, around the southern end of the main mass of the Rocky Mountains. The region includes the

[1] Manuscript received by the Secretary of the Society May 28, 1912.
This paper was presented under the title "Correlation of rocks in the isolated coal fields around the southern end of the Rocky Mountains in New Mexico."
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eastern part of the San Juan Basin, known also as the San Juan River region (107),[2] from the Colorado-New Mexico line southward to Cabezon, and the smaller fields to the southeast, namely, the Rio Puerco, Tijeras, Hagan, and Cerrillos coal fields. Observations were also made near Durango, in southwestern Colorado, in the type area of the Mesaverde formation. In addition to the observations made in these fields during the summer of 1911, some of the unpublished results previously obtained in the Raton coal field are used. The location of the area described is indicated on the accompanying sketch map, figure 1.

Purpose of Investigation

The purpose of this investigation was to determine the relation of the coal-bearing rocks east of the Rocky Mountains, in southern Colorado and northern New Mexico, to the coal-bearing rocks similarly located west of these mountains. The reason for undertaking it may be briefly stated as follows: Until recently the coal-bearing rocks in the Raton Mesa region east of the mountains were supposed to constitute a single formation, and this was correlated with the Laramie of the Denver Basin. However, a few years ago it was shown that the so-called Laramie of this region consists of two formations separated by an unconformity representing a time break of considerable magnitude, and that each formation was characterized by an extensive and well preserved flora. The flora of the lower formation, according to Doctor Knowlton, seems to prove that it is older than recognized Laramie, while that of the upper formation proves that this formation is post-Laramie in age.

West of the mountains, in the San Juan Basin, two coal-bearing formations occur in the upper part of the Cretaceous series. The younger one, at the top of the Cretaceous, has been correlated somewhat doubtfully with the Laramie, and the older one, or Mesaverde, is of Montana age and is separated from the "Laramie" by a thick formation of marine shale—the Lewis.

These two large areas of coal-bearing rocks—the Raton Mesa region and the San Juan River region—are situated on opposite sides of the Rocky Mountains, only 90 miles apart, but, unfortunately, none of the Cretaceous rocks extend continuously around the mountains to connect these two principal areas, so that continuous tracing of formations from one to the other is impossible. However, certain small isolated coal fields at the southern end of the main range of the mountains help to bridge

[2] The references to the publications cited in this paper are indicated by numerals, which correspond with those in "Bibliography and Notes" on pp. 659-686.

the gap. Furthermore, assuming, as is often done, that the first great uplift of the mountains occurred at the end of Cretaceous time, the post-Cretaceous unconformity found in the Raton Mesa region should be recognizable on the western slope and the post-Cretaceous formations east of the mountains should have recognizable counterparts on the western slope.

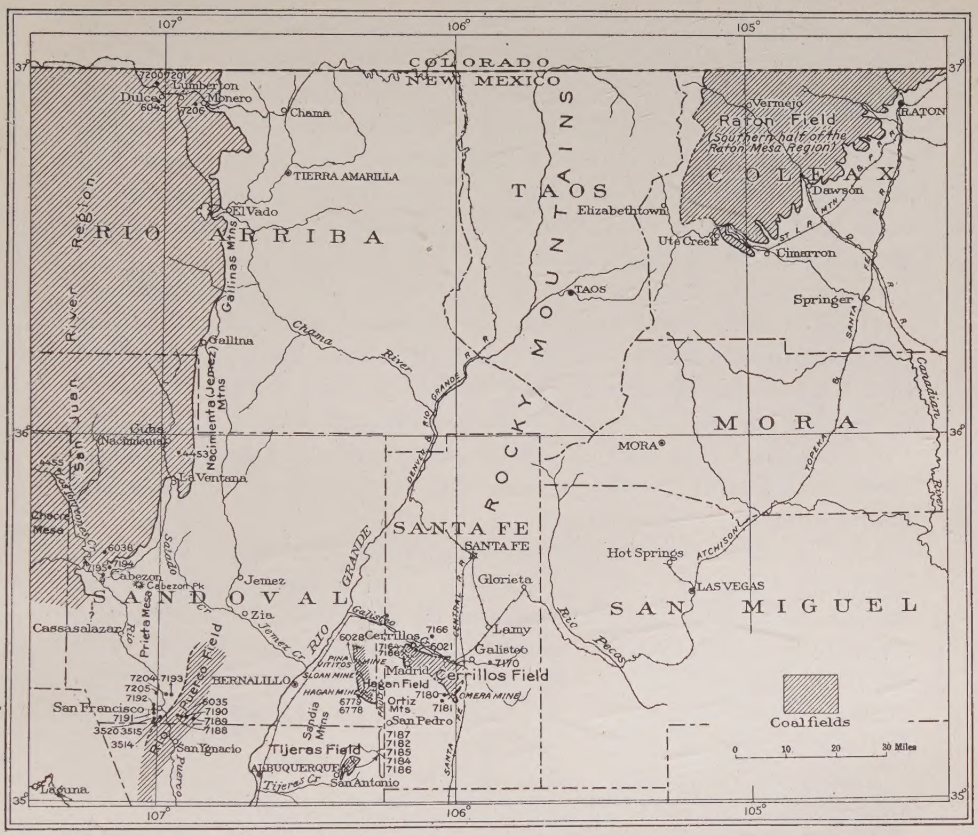

FIGURE 1.—*Map of Part of New Mexico, showing Location of Coal Fields*

The type of locality of the Mesaverde formation and the Lewis shale is in southwest Colorado, in the northern part of the San Juan Basin, where the Mesaverde is known to lie above shale that contains marine fossils of Pierre age, but relatively little has heretofore been known of the fossils contained in the Mesaverde, the Lewis, or the "Laramie" of this basin. In order, therefore, to correlate the formations east of the mountains, where good collections of both leaves and shells had been

made, with those west of the mountains, it was necessary to make collections from these three formations, as well as from the shale below the Mesaverde. This was done in all of the coal fields visited, and care was exercised to locate the collections as definitely as possible in measured sections.

Preliminary Statement of Results

The stratigraphic succession of the formations and their relation to each other were determined in each of the fields examined. The fossil plants collected have been examined by F. H. Knowlton and the fossil shells by T. W. Stanton. The correlations are based on the stratigraphic sequence of the formations, on lithologic resemblances, and on the fossils. Some of the propositions advocated in this paper may be regarded as essentially proved, others as fairly well sustained, while some are advanced only as working hypotheses.

Among the propositions that are regarded as essentially proved are:

(1) The thick shaale—the Mancos—below the principal coal-bearing formation in the southeastern part of the San Juan Basin is represented by a shale of similar character and essentially equivalent age in each of the smaller fields as far east as Galisteo. Although the top of this shale varies slightly in age from place to place, it represents a once continuous formation extending from the San Juan Basin eastward to some unknown distance beyond Galisteo.

(2) The principal coal-bearing rocks of the San Juan Basin—the Mesaverde formation—are represented by similar rocks in each of the smaller fields near the southern end of the Rocky Mountains, and although both the upper and the lower limits of the formation may vary somewhat in age from place to place, the coal-bearing rocks heretofore known as Laramie in these smaller fields are of essentially the same age as the Mesaverde of the San Juan Basin.

Among the propositions which may be regarded as probably true, although less well sustained than those noted above, are:

(1) The Mancos shale of the southeastern part of the San Juan Basin is essentially equivalent in age to the shale originally described as Mancos.

(2) The Mesaverde formation of the southeastern part of the San Juan Basin is lithologically similar to the original Mesaverde, but is thicker and may include rocks slightly younger than the typical Mesaverde.

(3) The base of the Mesaverde of the Rio Puerco field, as represented by the Punta de la Mesa sandstone, is several hundred feet lower in the

section than the base of that formation farther north. The Punta de la Mesa sandstone seems to be equivalent to a sandstone which in the vicinity of Cabezon occurs in the Mancos shale 500 feet or more below the base of the coal-bearing rocks—Mesaverde—of the San Juan Basin.

(4) The fossil plants from the so-called "Laramie" of the San Juan Basin indicate that this formation may be older than the Laramie of the Denver Basin.

(5) The flora of the coal-bearing rocks below the unconformity in the Raton field is similar to that of the Mesaverde, and tends to make that formation the time-equivalent of the Mesaverde. It has a less striking resemblance to the flora of the so-called "Laramie" of the San Juan Basin, which Doctor Knowlton regards as older than Laramie. On the other hand, the fauna of the shale immediately below the coal-bearing rocks of the Raton field is similar to that of the Lewis shale, and tends to correlate the older coal-bearing rocks with the "Laramie" of the San Juan Basin.

(6) Unconformities, representing erosion that probably took place after the close of the Cretaceous period, are found in all of the coal fields described in this paper. So far as is now known, this erosion originated in the post-Cretaceous uplift of the Rocky Mountains, but cut deeper in some places than in others, and persisted in some places longer than in others.[3]

Previous Investigations

In another section of this paper will be found a complete annotated list of the principal publications consulted during its preparation. Where practicable, the data that may be found useful in gaining a proper understanding of the geologic relations here discussed are enumerated. Among these publications there are many that give little new information, but are devoted principally to discussion or to reviews of papers previously published, and a few that have furnished practically all of the geologic information hitherto known. An attempt is made below to give a brief historic account of these investigations and place in chronologic order the principal contributions made toward an understanding of the geologic relations and age of the coals of central and western New Mexico and the rock formations with which they are associated. Most of those

[3] The results presented in this paper are so largely dependent on paleontology that more than ordinary credit should be given to Dr. T. W. Stanton, who identified the invertebrates and assisted the writer in other ways, and to Dr. F. H. Knowlton, who identified the fossil plants and placed at the writer's disposal a large volume of information not yet published, but which has a strong bearing on the problems of correlation.

relating to the Raton field have been omitted, for they will appear in another paper which is nearly completed.

Dr. A. Wislizenus (3) visited the gold fields south of Cerrillos in July, 1846, and although he makes no mention of coal in the Cerrillos field he observed the petrified wood that occurs in the Galisteo sandstone near the coal beds in this field, and states that coal occurs on the Rio Puerco in rocks supposed to be equivalent in age to those in the Cerrillos field. About two months later Lieutenant Abert (1) visited the Cerrillos field and found coal on one of the tributaries of Galisteo Creek. He also found coal on the Rio Puerco and collected fossils from rocks associated with the coal beds at Poblozon, a few miles north of San Ygnacio. According to J. W. Bailey, (2) these fossils proved the Cretaceous age of the coal-bearing rocks.

In 1849 James H. Simpson (4) visited the coal beds on the Rio Puerco at the eastern margin of the San Juan Basin northeast of Cabezon, and at several places farther west. Later, in 1853, Jules Marcou (6) reports coal "at Los Lunas and several other points on the Puerco," and compares the coal-bearing rocks with those of the Cerrillos field.

William P. Blake (9) examined the anthracite of this field in 1857, and also some coal in the Carboniferous formation near Santa Fe. He was inclined at this time to regard the Cerrillos anthracite as Carboniferous. A year later, in 1858, J. S. Newberry visited Santa Fe and secured samples of this anthracite, but did not visit the mine until the following year. He found coal beds near Fort Defiance, at the southern extremity of the San Juan Basin, in rocks which he referred to the Cretaceous, and others farther west, at Moqui, which he referred to the Jurassic. In 1859 he visited the Cerrillos coal field and examined both the anthracite and the "lignite" near Cerrillos and referred both to the Cretaceous. The full account of his investigation was not published until 1876, although a preliminary announcement of some of his conclusions was made in 1871.

In 1865 R. E. Owen (11) and E. T. Cox visited both the Cerrillos and the Rio Puerco coal fields. They referred the Cerrillos anthracite to the Carboniferous. In 1867 John L. Le Conte (13) visited the Cerrillos field and secured fossil leaves from the coal measures. From the evidence of these fossils he referred the coal beds to the Cretaceous, but placed them well down in the Cretaceous series. He regarded them as older than the "Marshall formation" or Laramie of the Denver basin. He also reports the occurrence of coal on the Rio Puerco west of Albuquerque. A year later he (15) reported the occurrence of coal near

Tijeras and referred again to the occurrence of coal in the Cerrillos and Rio Puerco fields, and near Tierra Amarilla in the San Juan Basin.

In 1869 Hayden (19), after a brief visit to the Cerrillos coal field, referred the coal beds to the Tertiary, basing his conclusion on the fossil plants which he found in abundance and which were later examined by Lesquereux. In 1870 Raymond (16) published a description of the coal beds of the Cerrillos and other coal fields, treating them from an economic standpoint. The following year Newberry (17) published a brief statement to the effect that the anthracite near Cerrillos is of Cretaceous age, and in 1872 Lesquereux (18) followed with descriptions of the fossil plants that had been collected from the Cerrillos coal measures and referred the beds containing them to the Tertiary, as Hayden had done three years before. A year later, 1873, (21) he correlated the Cerrillos coal beds with others which he regarded as Tertiary, notably with those at Raton, New Mexico (which have recently been shown to consist of two formations somewhat widely separated in time), and with the coal measures near Canyon City, Colorado, the age of which is still debatable. In the same article he refers to the coal measures in the Tijeras field, and also to coal near San Felipe—doubtless at the northern end of the Hagan field.

During the controversy over the geologic age of the "lignitic group" of Hayden, which raged in the early seventies, several more or less obscure references were made to the coal beds of northern New Mexico, but too little was known of them to bring them seriously into the controversy. Many of these are noted in the list of publications on pages 659-686, but need not be mentioned here, inasmuch as the character of the information contained is indicated by the notes accompanying the titles of the papers.

During the years 1871 to 1873, inclusive, certain explorations were made in regions west of the 100th meridian, including the areas described in this paper. Several geologists were connected with these explorations and published, in the Wheeler reports and elsewhere, many facts of interest regarding the coal measures of New Mexico. Loew (30) mentions the occurrence of "Cretaceous lignite beds" in the San Juan Basin near Nacimiento, and Cope (26) also published in 1874 a description of the coal measures exposed farther north in the same basin along the tributaries of the Chama River and elsewhere, in which he shows that marine rocks of Cretaceous age occur above the coal beds. These are evidently the Mesaverde coals of northwestern New Mexico, and the marine rocks above them constitute the Lewis shale of later writers.

Apparently Cope either did not find the "Laramie" of this region at this time or did not separate it from the overlying Tertiary rocks.

Again, in 1875, Loew (41) describes the "Cretaceous" coal beds near Nacimiento, and also those farther south on the Rio Puerco near San Ygnacio (42), as well as those in the Cerrillos and Tijeras coal fields. Analyses are given of the bituminous coal from Nacimiento and of the anthracite from Placer Mountain in the Cerrillos field. About the same time Stevenson presented a paper apparently not published until the following year, in which he mentions the Galisteo formation, and Cope (39) criticized the paper, stating that the Galisteo sandstone is Triassic in age (probably misled by the color of the rocks). The same error seems to have been made by others, for several contemporaneous writers refer to great numbers of petrified trees in the Trias of the Cerrillos region, whereas no rocks now admitted to be of Triassic age occur in this region, and all of the petrified wood known to the present writer is in the Galisteo sandstone. It does not appear from the literature that Cope actually visited the Cerrillos coal field at this time, as his route was from Santa Fe to the Sandia Mountains west of the field, but his descriptions are such as to indicate that he regarded the coal beds which he evidently knew lay east of his route as belonging in the Cretaceous, at least as high as number 4 (Pierre), inasmuch as his diagram (36) shows the occurrence of number 4 stratigraphically below the horizon where the coal is now known to occur. However, Stevenson (53) states that Cope referred the coal to Cretaceous number 3. In this same paper (36) Cope describes, in considerable detail, the coal measures west of Nacimiento Mountains. He referred the coal beds, which later writers have called Mesaverde, to Cretaceous number 3 (Niobrara), and found above them fossils which he regarded as indicative of Cretaceous number 4 (Pierre), which apparently is the Lewis shale, later described as occurring above the Mesaverde coal measures in this region. In another paper Cope (38) gives a graphic section of both Cretaceous and Tertiary formations, in which he indicates a covered area between his Cretaceous number 4 and the overlying Puerco formation.

In 1874 Cope (23) announced that he had found dinosaur bones which, in his opinion, proved that Hayden's "lignitic group" was Cretaceous in age, and Hayden (28) replied that he admitted the Cretaceous age of some of the coal beds of Utah, Arizona, and western New Mexico; also, Newberry asserted that he had proved the coal beds of New Mexico to be Cretaceous by the discovery of marine fossils above them (28 and 32), and that all of the plant-bearing coal beds in New Mexico are of

Cretaceous age, but Lesquereux (49) tried to strengthen his reference of the coal beds to the Tertiary by the evidence of the fossil plants.

In 1876 the delayed publication (44) of Newberry's account of his expedition with Macomb in 1859 appeared, and with it Meek's (43) description of the fossil shells collected by Newberry during that expedition. The coal beds of the Cerrillos field and those of the San Juan Basin are referred to "Middle Cretaceous," which, according to Newberry's classification, make them equivalent in time to the Niobrara. Cope (45) followed a year later with a paper, in which he referred these same coal beds, west of Nacimiento and Gallinas Mountains, to Cretaceous number 3, which, as just explained, is equivalent to the upper part of Newberry's "Middle Cretaceous." About a year later a striking example of the difference of opinion existing between the authorities of that time appeared when Lesquereux (49) included in his *Tertiary* flora plants from the coal measures of the Cerrillos field which Newberry (44) had previously referred to "Middle Cretaceous."

In 1877 Hayden's Atlas of Colorado was published and doubtless had great influence on such investigations as were later made in New Mexico. The mapping was extended southward over the area near Monero, described in this paper. By inspection it appears that the Colorado formation of this Atlas includes the shale both above and below the main coal beds which Newberry and Cope had referred to Cretaceous number 3. These are the coal beds which Schrader (100) later mapped as Mesaverde. The Atlas map shows the occurrence of a considerable development of so-called Fox Hills rocks in this region overlain by Wasatch. It is not clear what this "Fox Hills" is intended to represent, unless it be the very thin "Laramie" which occurs at Dulce and the massive sandstones of the post-"Laramie" formation, which is now known to lie unconformably on the "Laramie" in the vicinity of Dulce.

In 1878 and 1879 J. J. Stevenson examined the Cerrillos coal field and published (51) a preliminary account, in which he refers the coal-bearing rocks to the Laramie. At a time when such wide differences of opinion existed, as is indicated above, it would seem especially difficult to find the truth. Furthermore, Stevenson had worked east of the mountains in the Canyon City field and in the Raton Mesa region in beds which, by common consent, were called Laramie. Although some geologists had referred the Cerrillos coal beds to Cretaceous number 3 (Niobrara) and others had regarded them as younger than this, but still somewhat older than those of the Raton Mesa, Canyon City, and Denver fields, there seems to have been a general assumption at this time that the coal

beds of all these fields were of practically the same age, so that when those of the more northerly fields were called Laramie it was quite natural that Stevenson should extend the name to the Cerrillos field without presenting as clear evidence of age as could be desired. Thus, while Stevenson correlated the coal beds of the Cerrillos field with the so-called Laramie farther north, he held that the Laramie was Cretaceous. In other words, his Laramie was equivalent to the upper part of Hayden's Fox Hills group. In 1881 (52 and 53) the full account of Stevenson's investigation appeared, and although the coal beds are referred definitely to the Laramie, a step was taken toward their present reference to the Mesaverde when he reported (52, page 371) the occurrence of marine and brackish water fossils from "high up in the Laramie." It should be noted in passing that Stevenson's "Laramie" included not only the coal-bearing rocks, but many, if not all, of the younger rocks that other writers have described as Galisteo. The descriptions in his several papers on the Galisteo region, his maps of the region (54, number 77 (B), and number 78 (A)), and his cross-section (52 and 53, page 341, figure 49) leaeve no room for doubt that his "Laramie" includes the rocks of both the Mesaverde and the Galisteo formations of the present paper.

For several years after Stevenson's investigation little new information was gained concerning the coal measures of central and western New Mexico, but several more or less definite references to them are found in the literature. Cope, who was interested in the Tertiary vertebrates of northwestern New Mexico, makes mention of the underlying coal beds (55), which he refers, in part at least, to the Laramie. The coal beds of Gallinas Mountains are shown as occurring below "Fox Hills" (57), and the Puerco and Laramie are included under "post-Cretaceous," although Cope explains in the text that the Puerco belongs in the "Tertiary rather than the post-Cretaceous."

Little work was done on the coal-bearing rocks of New Mexico during the nineties, although Stevenson (69) visited the Cerrillos coal field again in 1896 and added a little to the information that he had already given. However, observations were being made by Cross, Spencer, and others in southwestern Colorado that were destined to have a notable influence on the investigations of the New Mexico coal-bearing rocks. In 1898 Spencer (73) announced that rocks of Benton, Niobrara, and Pierre age in southwestern Colorado are not divisible on lithologic grounds, and that massive sandstones occur higher in the section which might prove to contain equivalents of both Fox Hills and Laramie. This was followed a year later (75) by the La Plata folio, in which Cross names the coal-bearing rocks *Mesaverde,* the shale between them and the

Dakota *Mancos,* and the shale overlying them *Lewis.* The younger coal-bearing rocks, or "Laramie," occur in this region beyond the limits of the La Plata folio, thus making a section of the Cretaceous rocks which has become the standard for southwestern Colorado and northern New Mexico.

While the work just referred to was in progress in southwestern Colorado a series of independent investigations was being carried on by C. L. Herrick, then president of the University of New Mexico, and by others associated with him. They were not in close touch with other investigators, and although their work yielded much valuable information the results have not received the attention they deserve. In 1898 Herrick (72) published a preliminary paper, describing some of the Cretaceous rocks near Albuquerque, and two years later a more elaborate report on this region appeared, in which he, in collaboration with Johnson (77), described the stratified rocks extending from the Rio Puerco to the Cerrillos coal field. Much valuable information was given regarding the Cretaceous rocks below the coal beds, and the coal-bearing rocks were shown on fossil evidence to be of the same age in the Rio Puerco, Hagan, Tijeras, and Cerrillos coal fields and to be older than the Laramie. They were referred to the Fox Hills. This paper was followed in 1903 by one from D. W. Johnson (83), in which the geology of the Cerrillos region is described in detail. The coal measures were referred to the Fox Hills, and a somewhat extensive Pierre fauna was found in the shale below the coal; also a somewhat extensive Benton fauna was found near the bottom of this shale formation, but no fossils characteristic of the Niobrara were obtained. Evidence was found in some places of a commingling of Benton species with some that he regarded as characteristic of the Pierre.

The work of Herrick and Johnson was not extended to correlate in any way the rocks described by them with those described by Cross and others in southwestern Colorado, and their results, proving that the coal beds of central New Mexico are older than Laramie, seem not to have gained acceptance, for as late as 1907 Campbell (103), in writing of the coal beds of the Cerrillos and Hagan fields, states that "it is highly probable that they are Laramie."

In 1905 work was begun on the coal fields of New Mexico which has resulted in a series of publications leading up to our present knowledge of the coal fields. Schrader (100) traced the Mesaverde and "Laramie" formations from southwestern Colorado, where Cross had established their stratigraphic relations, eastward along the northern border of the San Juan Basin and southward to the Gallinas Mountains. Farther south the "Laramie" was not identified and the coal-bearing rocks

are described as "Upper Montana—relation to the Mesaverde unknown." This was followed in 1907 with a paper by Shaler (105), who traced the formations of southwestern Colorado around the western margin of the San Juan Basin.

In 1908 a paper was published by Shimer and Blodgett (109) which aids materially in correlating the coal measures of the Rio Puerco field with those of the San Juan Basin. These observers collected fossils at several localities between the two coal fields from the fossil-bearing zones that had been described by Herrick and Johnson as occurring in the shale below the coal beds of the Rio Puerco field.

A year later, 1909, Gardner (110) referred Schrader's "Upper Montana group" of the southeastern part of the San Juan Basin to the Mesaverde and found the Lewis shale and the "Laramie" coal beds higher in the section. This was followed by two papers from the same writer (116 and 117) in which these correlations were strengthened.

In 1905 the present writer began making observations in New Mexico, and in the following year (97) announced the discovery of bones of Triceratops in rocks younger than the coal measures near Engle, New Mexico, about 150 miles south of the area described in the present paper. These rocks have a conspicuous basal conglomerate that was later found to lie unconformably on the coal-bearing rocks.[4] In this and in a later paper (104) these rocks were provisionally correlated with the Galisteo sandstone of the Cerrillos coal field, and there in turn with the post-Laramie beds found elsewhere, which were at that time and still are by some geologists regarded as being of late Cretaceous age. The next step taken by the writer in this study was in 1908, when he discovered an unconformity announced in 1911 (111) in the Raton coal field of New Mexico. The coal-bearing rocks previously referred to the Laramie were found to be separated by this unconformity into two formations, the upper one of which was correlated on fossil evidence with the post-Laramie rocks of the Denver Basin, while the lower one contains a flora that is regarded as older than Laramie. In 1910 the writer, assisted by J. B. Mertie, spent the field season in tracing the coal-bearing formations around the Raton and Trinidad coal fields and in studying their relations to each other and to neighboring formations. A preliminary announcement of results was made (119), in which it was shown that the unconformity is readily traceable in all parts of these two fields. A large amount of evidence was collected bearing on the structural relations and the geologic age of these two coal-bearing formations, but the information is not yet

[4] Personal communication from Mr. Max W. Ball.

in form for publication. The greater part of the evidence of age is derived from fossil plants which are being studied by Dr. F. H. Knowlton. Although his study of them is by no means complete, it has progressed far enough to indicate that, in his opinion, the plants of the upper formation are undoubtedly of post-Laramie age, and that those of the lower formation are older than recognized Laramie.

During the summer of 1911 the writer carried on the investigations described in this paper in an attempt to correlate the formations of the Raton Mesa region with those of the coal fields south and west of the Rocky Mountains. A preliminary statement of results was given at the Washington meeting of the Geological Society of America, in which it was shown that the evidence derived from the study of stratigraphy, of fossil plants, and of fossil shells all agree in correlating the coal beds of the Cerrillos, Hagan, and Rio Puerco coal fields with the Mesaverde formation of the southeastern part of the San Juan Basin, and that the fossil plants associated with these coal beds are essentially the same as those found in the coal-bearing formation below the unconformity in the Raton Mesa region.

After the present paper was in type, but before it went to press, the writer, in company with T. W. Stanton, made some examinations in the Rio Puerco field and along the eastern margin of the San Juan Basin from Cabezon to Monero, principally for the purpose of determining the relations of the coal-bearing rocks in the southeastern part of the San Juan Basin to the typical Mesaverde in the northern part of this basin. The results of this work cannot be embodied in the present paper, but it may be briefly stated (1) that at least the lower part of the coal-bearing rocks at Cabezon is essentially equivalent to the Mesaverde as represented at Monero, which in turn is the undoubted equivalent of the original Mesaverde, and (2) that these same rocks seem to be equivalent in age to the middle and upper portions of the coal-bearing rocks in the Rio Puerco field: in other words, that the base of the Mesaverde in the Rio Puerco field, as represented by the Punta de la Mesa sandstone, is lower in the section by several hundred feet than the base farther north, and that these several hundred feet of sandstone and sandy shale are equivalent in age to the upper part of the Mancos near Cabezon.

Geologic Formations

THE TYPE SECTION

In 1899 Whitman Cross (75) published a section of the Cretaceous rocks that has become the standard for southwestern Colorado and western New Mexico. This section divides the Cretaceous into Dakota sand-

stone, Mancos shale, which is equivalent in age to Benton, Niobrara, and a part of Pierre; Mesaverde formation, Lewis shale, "Pictured Cliffs sandstone," and "Laramie" formation. The "Pictured Cliffs sandstone" may be regarded as the basal sandstone of the "Laramie" formation. The Animas formation, lying unconformably on the "Laramie," was correlated with the post-Laramie formations of the Denver Basin, which were then generally referred to the Cretaceous, but which have recently been referred to the Tertiary by G. B. Richardson (122).

This subdivision of the Cretaceous finds its latest expression in a section measured by J. H. Gardner, a few miles east of Durango, for use in a folio now in preparation. At the writer's solicitation Doctor Gardner has prepared the section for use in this paper as follows:

Section of Cretaceous Rocks measured on Florida River near Durango, Colorado (except the Wasatch, which was measured farther East)

(Data furnished by J. H. Gardner)

		Feet	In.	Feet	In.
Wasatch as determined by vertebrate remains. (Section measured on east side of Ignacio Quadrangle.)	Sandstone, massive ledges, coarse-grained, tan-colored, with thin beds of shale	80			
	Sandstone alternating with beds of shale	70			
	Sandstone, massive, tan-colored	20			
	Shale, variegated and thin sandstone	100			
	Sandstone, massive, coarse-grained, gray	30			
	Shale, gray and drab	50			
	Sandstone, tan-colored, coarse-grained, with lenses of colored quartz and chert, average bird-egg in size	20			
	Shale, variegated with lenticular beds of brown and gray sandstone	400			
	Shale, variegated with benches of gray sandstone and thin ferruginous sandstone and sandy shale	660			
	Sandstone, massive, soft, gray	20			
	Shale, variegated	50			
	Sandstone, massive, coarse-grained, dark-gray but locally purplish-brown	4			
	Shale, variegated with brown, reddish, gray and drab, with thin beds of brown and gray sandstone	325			
	Shale, brownish and reddish, with lenses of conglomeratic sandstone; pebbles of colored quartz and chert chiefly	85			
	Shale, yellowish and gray	50			
	Sandstone with small pebbles of quartz	1			
	Shale, yellowish, drab and gray	60			
	Shale, tan-colored and reddish at the base, containing *Platanus reynoldsii* Newb. ? at the base	250			
				2,275	

(Lithologic contrast. Unconformity not perceptible.)

		Feet	In.	Feet	In.
Animas formation	Sandstone, massive, tan-colored, micaceous with greenish igneous debris, alternating with yellowish shale	50			
	Shale, brown, drab, gray, and some reddish	75			
	Sandstone, tan-colored, alternating with heavy beds of brown, greenish, drab, and yellowish shale, containing *Ficus* sp. ? and *Cornus* sp. 109 feet from the top and *Artocarpus lessigiana* (Lesq.) Kn.; and *Nyssa* ? *racemosa* ? Kn. 275 feet from the top	855			
	Sandstone, greenish-gray, with small igneous pebbles one-quarter inch in diameter in irregular zones	50			
	Shale and sandstone, greenish, locally conglomeratic	250			
	Shale, greenish	60			
	Sandstone, greenish and pink, with pebbles of schist and quartzite chiefly; pebbles 1 to 10 inches	20			
	Shale, greenish	15			
	Sandstone, greenish-gray, coarse, friable	10			
	Shale, greenish, and conglomeratic sandstone	20			
	Shale, carbonaceous	1			
	Shale, drab	2			
	Shale, carbonaceous	1			
	Shale, greenish, with silicified wood	81			
	Sandstone, gray and ferruginous, with sandstone concretions	10			
	Shale, dark red, bluish and drab	250			
	Sandstone, argillaceous, with andesite and other igneous pebbles and tuffs	20			
	Sandstone and shale with igneous matrix and pebbles	20			
	Shale, greenish and purple	50			
	Sandstone, yellowish	20			
	Shale, greenish, purple and bluish	20			
	Sandstone, massive, poorly consolidated, yellowish-white, and cross-bedded; contains *Ficus planicostata* Lesq. at the base	50			
	Sandstone, argillaceous, and some shale; igneous matrix	85			
	Tuff, coarse fragments of various composition	12			
	Shale, reddish, alternating with dark conglomerate and sedimentary debris	28			
	Tuff, reddish and pink, coarse-grained	7			

		Feet	In.	Feet	In.
Animas formation	Sandstone, brown, fine-grained, with round sandstone concretions	8			
	Shale, irregularly bedded, gray, friable	1	8		
	Sandstone, brown, coarse-grained, igneous matrix	4			
	Sandstone, yellowish and locally reddish	1			
	Sandstone, drab-colored weathers reddish, igneous matrix	15			
				2,091	8
	(Unconformity by erosion, and discordance of dip.)				
"Laramie"	Shale, yellowish, with sometimes a white sandstone near the top	50			
	Shale, drab-colored with some thin sandstone	100			
	Sandstone, massive, light colored	20			
	Shale, tan and gray	90			
	Sandstone, massive, soft, gray	12			
	Shale and soft sandstone containing at the base *Unio holmesianus* White; *Unio* sp.; *Corbicula* sp.; *Corbula subtrigonalis* M. & H.; *Tulotoma thompsoni* White; *Goniobasis* ? sp.; *Campeloma* ? sp. (U. S. G. S. locality No. 6063)	20			
	Sandstone, massive, rather hard, gray	20			
	Shale, brownish, and thin, soft sandstone	320			
	Sandstone, friable, gray		6		
	Sandstone, brown, containing *Brachyphyllum macrocarpum* Newb. and *Sequoia reichenbachi* (Gein.) Heer (U. S. G. S. locality No. 5462)	2			
	Sandstone, gray	15			
	Shale and some thin sandstone	30			
	Shale and thin sandstone, containing *Sequoia reichenbachi* (Gein.) Heer; *Carpites* sp.; *Juglans* sp.; *Salix* sp.? (U. S. G. S. locality No. 5463)	19			
	Coal bed	1			
	Shale and thin sandstone	10			
	Sandstone, soft in several beds	35			
	Shale	8			
	Coal bed "C"	3	1		
	Shale, carbonaceous	15			
	Coal bed		8		
	Shale, dark and drab	20			
	Sandstone, massive, gray with calcareous layer near base	50			
	Sandstone and shale, containing *Pholas* ? sp.; *Goniobasis* ? sp.; *Campeloma* ?				

		Feet	In.	Feet	In.
	sp.; *Viviparus* sp. (U. S. G. S. locality No. 6064) 43 feet above the base and fossil plants at the base....	150			
	Shale, containing both fresh water and brackish water invertebrates as follows: *Unio brachyopisthus* White; *Unio holmesianus* White; *Unio*, 2 undescribed (?) species; *Sphœrium* sp.; *Martesia* ? sp.; *Viviparus* sp.; *Compeloma* ? sp.; *Tulotoma thompsoni* White; *Ostrea* sp.; *Corbicula* sp., related to *C. subelliptica* M. & H.; *Corbicula* sp.; *Corbula* sp.; *Melania* sp.; (U. S. G. S. locality Nos. 6071, 6072, and 6074), and fossil plants *Viburnum marginatum* Lesq. ? (U. S. G. S. locality No. 5454).....	10			
	Coal bed "B".....	12	2		
"Laramie"	Shale and thin sandstone, containing, 15 feet from the top, *Ostrea* sp.; *Anomia* sp.; *Modiola laticostata* White; *Corbula subtrigonalis* M. & H.? (U. S. G. S. locality No. 6065); 20 feet from the base are the fossil plants *Sequoia reichenbachi* (Gein.) Heer; *Quercus* sp., and at the base both shells and plants, *Anomia* sp.; *Corbula subtrigonalis* M. & H.?; *Cypris* ? sp.; *Melania* sp. (U. S. G. S. locality No. 6068), and *Brachyphyllum macrocarpum* Newb.; *Geinitzia formosa* Heer; *Sequoia reichenbachi* (Gein.) Heer (U. S. G. S. locality No. 5451).	50			
	Coal bed "A".....	3			
	Shale, dark and drab.....	4			
		——		1,090	5

			Feet	In.	Feet	In.
"Laramie"	Pictured Cliffs Sandstone	Sandstone, gray, massive, top of "Pictured Cliffs sandstone," containing both invertebrates and plants: *Ostrea* sp.; *Inoceramus barabini* Mort.; *Cardium speciosum* M. & H.; *Tellina scitula* M. & H.; *Anomia* sp.; *Corbula subtrigonalis* M. & H.? (U. S. G. S. locality Nos. 6067, 6069, 6070), and *Geinitzia formosa* Heer? *Abietites dubius* Lesq. (U. S. G. S. locality Nos. 5446 and 5448)	75			
		Shale, drab colored	15			
		Sandstone, massive, brownish	6			
		Shale, carbonaceous and coaly	3			
		Shale, drab colored	10			
		Sandstone, massive, gray	10			
		Sandstone, massive, gray with some alternating shale beds, bottom of "Pictured Cliffs sandstone," containing at the base *Ostrea* sp.; *Inoceramus* sp.; *Corbula* sp.; *Odontobasis* ? sp. (U. S. G. S. locality No. 6066)	75			
		Transition sandy shale with beds of sandstone 6 inches to 1 foot thick	200			
					394	
Lewis		Shale	1,600		1,600	
Mesaverde		Sandstone, massive, light gray	10			
		Shale and sandstone	80			
		Coal bed		10		
		Sandstone and shale	170			
		Sandstone, massive, gray	20			
		Coal bed	2	7		
		Shale and sandstone	28			
		Coal bed	1	8		
		Shale	12			
		Coal bed	2			
		Shale	8			
		Coal bed	1	3		
		Shale and sandstone	12			
		Coal bed	4	6		
		Shale	10			
		Coal streak sometimes present here.				
		Sandstone, massive, gray, containing *Ficus lanceolata* ? Heer	60			
					422	10

		Feet	In.	Feet	In.
Mancos	Shale with transitional beds of thin sandstone and shale at the top, containing *Gryphœa newberryi* Stanton, 60 feet above the base, 1,200 to 2,000 feet thick.....	1,600±			
				1,600±	
Dakota and sandstones at base of Mancos	Sandstone, massive, gray, quartzose.....	20			
	Shale, dark and gray, with local thin coal beds and some shaly sandstone.....	40			
	Sandstone, massive, gray, quartzose.....	50			
	Shale and thin sandstone with local carbonaceous layers and thin coal beds.....	100			
	Sandstone, massive, gray, quartzose.....	15			
				225	
	Total.....			9,698	11

In order to correlate the formations described from central New Mexico with those of the Durango region, the writer made a somewhat hasty trip to Durango, where the Cretaceous formations are well exposed along the Animas River. Careful search was made for fossils in the Mesaverde, Lewis, and "Laramie." None were found in the Lewis, and the Mesaverde was found to be barren in many places, although a few shells and poorly preserved fossil leaves were found in it. Half a mile west of Twin Buttes, at the mouth of the gulch, entering Lightner Creek from the west, several fossil plants were found, but most of them are too poorly preserved to be specifically identified. They are *Equisetum* sp., *Sequoia reichenbachi* (Gein.) Heer, Fern, *Quercus* sp., *Quercus* n. sp., Palm, and *Ficus* sp. (United States Geological Survey, locality No. 6043). In this gulch, half a mile farther west, *Baculites anceps* var. *obtusus* Meek was found above the main coal beds. A single palm, *Geonomites* sp., very similar if not identical with a species common in the lowest coal formation of the Raton coal field, was found on the dump of an old mine in the Mesaverde coal, which opens in the gulch about 1 mile south of the Durango smelter, and on the dump of another mine in Horse Gulch, in the same coal measures, about half a mile east of Durango, *Ficus lanceolata* Heer and *Ficus* sp. were found. The fossil leaves seemed to be confined to very restricted zones closely associated with the coal. *Baculites anceps* var. *obtusus* Meek was found in the Mesaverde above the coal in several places near Durango. Such limited observations as were made in this region gave the impression that the Mesaverde is here essentially a marine formation. This observation seems to be verified by the work of other geologists. Fossils collected from this formation several years ago and identified by Doctor Stanton are as follows:

Mesaverde Fossils collected by Robert Forrester in southwestern Colorado

Anchura newberryi Meek
Acteon intercalaris Meek
Baculites anceps var. *obtusus* Meek
" *compressus* Say
Callista deweyi M. & H.
Cardium bellulum Meek
" *speciosum* M. & H.
Dentalium sp.
Fasciolaria sp.
Fusus sp.
Inoceramus barabini Morton
Lucina sp.
Lunatia sp.
Odontobasis sp.
Ostrea subtrigonalis E. & S.
Pinna sp.
Panopæa sp.
Placenticeras intercalare M. & H.
Serpula sp.
Sphæriola sp.
Turritella sp.

The coal-bearing formation above the Lewis shale, near Durango, has somewhat generally been regarded as Laramie because of its stratigraphic position. These beds were found to be very fossiliferous in some places. Some of the fossils throw doubt on the Laramie age of the formation, but for the purposes of this paper it will be called "Laramie" in order to avoid introducing a new name. Doctor Gardner found several fossils in it and these are named in the foregoing section. The best collection obtained from it by the writer contains both plants and invertebrates. They were found in the west wall of Animas Canyon, half a mile south of Carbon Junction, about 200 feet above the lowest or principal bed of coal. A few fossil leaves were collected from lower horizons in the same formation near this locality by J. A. Taff in 1906, and by J. H. Gardner in 1909. In order to make the flora of this locality complete, these have been included in the following list and are marked thus (*):

Fossils collected on or near the Animas River, in the Durango Region, Colorado

(Plants, United States Geological Survey, Locality No. 6044)

Ficus speciosissima Ward
Ficus trinervis Kn.
Ficus lanceolata Heer
Ficus sp. (3-nerved, narrow)
Quercus n. sp.
Geonomites sp.
**Abietites dubius* Lesq.
**Brachyphyllum macrocarpum* Newby.
**Carpites* sp.
**Geinitzia formosa* Heer
**Sequoia reichenbachi* (Gein.) Heer

(Shells, United States Geological Survey, Locality No. 7197)

Unio holmesianus White
" sp. related to *U. aldrichi* White
" sp.
Neritina sp.
Tulotoma thompsoni White?
Campeloma? sp.
Viviparus sp.

In commenting on the age of these fossils, Doctor Knowlton says of the plants:

"Notwithstanding the fact that this collection is from rocks generally regarded as of Laramie age, there is not a single species in it that suggests the Laramie (of the Denver Basin). It is the same flora as that at Point of Rocks, Wyoming, and so far as I can see is of the same age, namely, Montana."

The shells collected by the writer are beautifully preserved, but they are of fresh-water species. Doctor Stanton says of them:

"I consider this a Laramie fauna. The unios are Lance types and the gastropods are of types that range from Mesaverde to Lance."

In addition to the fossils named above, a number of invertebrates have been collected from the "Laramie" of southwest Colorado by Robert Forrester (113, page 274) and J. A. Taff. Their collections have been joined with those made by the writer and by Doctor Gardner to make the following list, which includes all of the invertebrates known from the "Laramie" of southwest Colorado. The marine forms come from the Pictured Cliffs sandstone and the brackish water forms from the lower part of the shaly portion of the "Laramie" formation, although many of the latter occur above the principal coal bed. The fresh-water forms are from higher horizons:

Fossil Invertebrates of the "Laramie" Formation of southwest Colorado

Anomia sp. related to *A. micronema* Meek
Anomia sp.
Campeloma? sp.
Cardium speciosum M. & H.
Corbicula sp. related to *C. subelliptica* M. & H.
Corbicula occidentalis M. & H.
" sp.
Corbula undifera Meek
" *subtrigonalis* M. & H.
" sp.
Cypris? sp.
Goniobasis? sp.
Inoceramus barabini Morton
Inoceramus sp.
Martesia? sp.
Melania wyomingensis Meek?
" sp.
Modiola laticostata White
Neritina sp.
Ostrea sp.
Phosas? sp.
Sphærium sp.
Tellina scitula M. & H.
Tulotoma thompsoni White
Unio holmesianus White
" *brachyopisthus* White
" *verrucosiformis* Whitfield?
" sp. related to *U. aldrichi* White
" sp. undescribed, possibly 2 species
Viviparus sp.

The relation of the so-called Laramie to the younger formations exposed along the Animas River is not yet satisfactorily determined. Several hundred feet above the horizon of the fossils collected by the present writer there is a distinct change in lithology. A hard, massive, cliff-

making sandstone rests with uneven base on shale, and in the lower part of this sandstone was found a large bone, apparently a shoulder-blade. Only a small part of the bone was secured, and on examination it proved to be a Dinosaur bone, but no more definite identification was possible. This sandstone was not observed over a wide enough area to assert that it rests unconformably on the "Laramie," but the abrupt change in lithology and the uneven base of the sandstone suggest that it may be the lowest of the Tertiary formations. The presence in it of a Dinosaur and its position below the Animas formation, which has usually been regarded as equivalent in age to the Denver formation, suggests the possibility that the sandstone may be the time equivalent of the Arapahoe formation of the Denver Basin. This sandstone does not seem to be present on Florida River, where Doctor Gardner measured his section, unless the white sandstone at the top of the "Laramie" of that section, which is not always present, represents it.

The Cretaceous formations of the Durango region and their age relations are shown in tabular form below. The member and zone names used first in the Rio Puerco field have been added to this table, and also the Tertiary formation, so that the table expresses the age relations of all of the fields described in the following pages. With the exception of the Animas beds, there is no doubt of the Tertiary age of the rocks above the "Laramie" in the San Juan Basin. In the other fields described rocks of similar appearance and composition hold the same stratigraphic position, but their Tertiary age has not been proved. A massive sandstone, probably equivalent to the Pictured Cliffs sandstone member, was observed near Dulce and at the southern outcrop of the "Laramie" of the San Juan Basin northwest of Cabezon. The Punta de la Mesa sandstone member is the base of the Mesaverde in the Rio Puerco field. A similar sandstone occurs at the base of this formation in all the other fields described. The Cephalopod zone was first described in the Rio Puerco field, but was recognized also in the Hagan and Cerrillos fields. The Concretion (Septaria) zone was described first from the Rio Puerco field (77) as occurring "sometimes above and sometimes below" the Tres Hermanos sandstone. It seems to be of doubtful value as a horizon marker beyond the limits of the Rio Puerco field. The Tres Hermanos sandstone is typically developed in the Rio Puerco field, but is readily recognized in the Tijeras, Hagan, and Cerrillos fields, and is probably represented throughout the San Juan Basin. The Gastropod zone is best developed in the Rio Puerco field. It is sparingly fossiliferous in the Cerrillos and Hagan fields, and in the Tijeras field is repre-

sented by limestone concretions from which no fossils have yet been collected.

Table showing the Age Relations of the Cretaceous Formations of central and western New Mexico and southwestern Colorado

Systems	Groups	Formations	Zones and members
Tertiary		Galisteo of Cerrillos field and Tertiary formations of San Juan Basin	
Cretaceous	Montana	"Laramie"	"Pictured Cliffs sandstone" member
		Lewis shale	
		Mesaverde	Punta de la Mesa sandstone member*
	Colorado	Mancos shale	Cephalopod zone
			Concretion (Septaria) Zone
			Tres Hermanos sandstone member
			Gastropod zone
		Dakota sandstone	

DAKOTA SANDSTONE

A quartzose sandstone locally conglomeratic occurs at the base of the Cretaceous series in northern New Mexico. No fossils have been found

* The Punta de la Mesa sandstone at its type locality in the Rio Puerco field is here placed at the base of the Mesaverde, inasmuch as it is the lowest sandstone of the coal-bearing formation. However, it seems to be the age equivalent of a part of the Mancos shale as developed farther north.

in it, but because of its stratigraphic position and its lithologic character it is referred to the Dakota.

The so-called Dakota sandstone east of the Rocky Mountains in Colorado consists of two plates of sandstone separated by a thin shale. This shale, together with the underlying plate of sandstone, has been proved to be of Lower Cretaceous age, leaving only the upper plate in the Dakota (92 and 121). The writer has observed similar relations as far south as Las Vegas, New Mexico. However, no rocks of Lower Cretaceous age are known to exist west of the mountains unless the Morrison be of Lower Cretaceous age and the sandstone between the Morrison and the lowest shale of the Mancos constitutes the Dakota of this paper. This sandstone was found in all of the coal fields here described, and the few observations made on it are presented in the section of this paper devoted to the presentation of details of the areas examined.

MANCOS SHALE

The Mancos shale of central New Mexico includes the rocks, mainly shale, above the Dakota sandstone and below the basal sandstone of the Mesaverde. According to Schrader (100), Gardner (110 and 116), and others who have traced the Cretaceous formations from the Durango region eastward and southward through the San Juan River region into the area described in this paper, this formation is essentially equivalent to the Mancos of southwest Colorado (75). The present writer examined it at three localities in the San Juan Basin, namely, at Durango, in southwest Colorado; at Monero, and at Cabezon, in New Mexico. It is continuously exposed between Cabezon and the Rio Puerco field, but east of the Rio Puerco it disappears under a cover of Tertiary and Quaternary sand and gravel in the Rio Grande Valley, and nothing is known there of its occurrence and extent. East of the Rio Grande the surface is occupied by Paleozoic and older rocks of the Sandia Mountain block, on the eastern slope of which the Mancos and younger rock formations reappear, so little changed from their appearance on the Rio Puerco that even without the aid of fossils it would be difficult to believe that they were not once continuous between the two fields. But this similarity in the lithology and stratigraphic succession is confirmed by the fossils contained in them and leaves little room for doubt that the sea in which the Mancos shale was deposited extended from the San Juan Basin eastward over the Hagan-Cerrillos region.

When detailed observations are made on the Mancos of central and western New Mexico it will probably be subdivided into at least three formations, but for the purposes of this paper it will be preferable to

avoid the introduction of new names and to refer to the subdivisions as zones and members, using the names adopted by Herrick and Johnson (77) as follows:

The *Gastropod zone* occurs near the base of the Mancos in a shale formation 35 to 100 feet thick. In the shale are lenses and concretions of earthy limestone which contain great numbers of fossils in the Rio Puerco field. This shale is readily recognized in the other coal fields here described, but the fossils contained in it elsewhere are not so numerous as they are on the Rio Puerco. In the Cerrillos field it contains thin beds of coal near the base and in the Rio Puerco field carbonaceous shale. It seems probable that this may be the horizon of some of the so-called Dakota coal of the southwest.

Above this shale is a series of yellow sandstones about 150 feet thick on the Rio Puerco and thinner in some of the other fields. It thickens westward and thins toward the east. Herrick and Johnson called it the *Tres Hermanos sandstone,* and this name may be used to designate the zone of yellow sandstone that occurs near the base of the Mancos in all of the fields described in central New Mexico west of the mountains. It seems to represent some of the sandstones of Benton age which are coal-bearing in western New Mexico.

The principal part of the Mancos shale occurs above the Tres Harmanos sandstone. It is a more or less homogeneous shale 1,200 to 2,000 feet thick in the Durango region, about 1,000 feet thick in the Rio Puerco field, and considerably thicker in the fields east of the Rio Grande. It is not divisible lithologically into Benton, Niobrara, and Pierre, but the fossils contained in it prove that it contains time equivalents of the Benton, probably the Niobrara, and some of the Pierre. Two zones of fossiliferous concretions have been described within this shale in the Rio Puerco field, but it is not known how definitely they can be recognized in other fields and their value as horizon markers is doubtful. A *Concretion (Septaria) zone* occurs in the Rio Puerco field (77) in close association with the Tres Hermanos sandstone. This zone was recognized by Shimer and Blodgett (109) in several places between the Rio Puerco field and Cabezon, but its occurrence east of the Rio Grande is doubtful. A *Cephalopod zone* (77) occurs in the Rio Puerco field 600 feet or more stratigraphically above the Concretion zone. It is characterized by great numbers of limestone concretions containing cephalopods and other shells. This zone seems to be fairly persistent throughout the Rio Puerco coal field and to be recognizable in many places between this field and Cabezon. East of the Rio Grande a zone of concretions containing the fauna of the Cephalopod zone occurs about 700 feet above the base of the Mancos

shale and seems to be the time equivalent of the Cephalopod zone of the Rio Puerco field. The fauna of the Cephalopod zone occurs in some of the concretions formerly supposed to indicate the Concretion (Septaria) zone, and there seems to be confusion regarding the latter zone. It is probable that some of the two invertebrates described from the latter belong to the Cephalopod zone.

The determination of the place at which the top of the Mancos should be drawn in the time scale involves some difficult questions. In its type area in southwestern Colorado this shale includes at its top rocks of Pierre age (73). The shale below the coal-bearing rocks in the Cerrillos field seems to have the same range, but in the Rio Puerco region fossils indicative of Benton age occur near the top of the shale. According to Mr. Schrader and Doctor Gardner, previously quoted, the Mancos shale was traced from the Durango region east and south to Cabezon. But as has formerly been stated, the upper part becomes sandy farther south, and in the Rio Puerco field is not readily separated from the overlying Mesaverde.

East of the Rio Grande the Mancos shale is much thicker than it is in the Rio Puerco field. At Hagan it has a measured thickness of 2,116 feet. A characteristic Benton fauna occurs in the lower 700 feet or more of this shale, but the upper part contains fossils that range upward through the Mesaverde. The few fossils found at the top of the Mancos near Hagan were close to the basal sandstone of the Mesaverde, but in the Cerillos field this fauna seems to extend downward 200 feet or more into the shale. In this latter field the Mancos has a measured thickness of 2,402 feet. The lower part of it is clearly of Benton age and some of the rocks are probably of Niobrara age. The upper part contains a great number of fossils that belong in the fauna of the Lower Montana. This occurrence of Montana fossils below the Mesaverde necessitates the reference of the rocks containing them to a horizon near the base of the Pierre. In order to bring out more clearly the fact that the Mancos shale on the Rio Puerco is faunally similar to only the lower part of this shale farther east, the fossils from the lower part are listed separately from those of the upper part, although all belong to the same formation.

The fossil invertebrates of the Mancos are included with those of the Mesaverde and the Lewis in the following table, and their general distribution is indicated therein. Unfortunately, a great many of the species have never been described, and their names as published in the table are of little value in correlation. However, in a report on the fossils

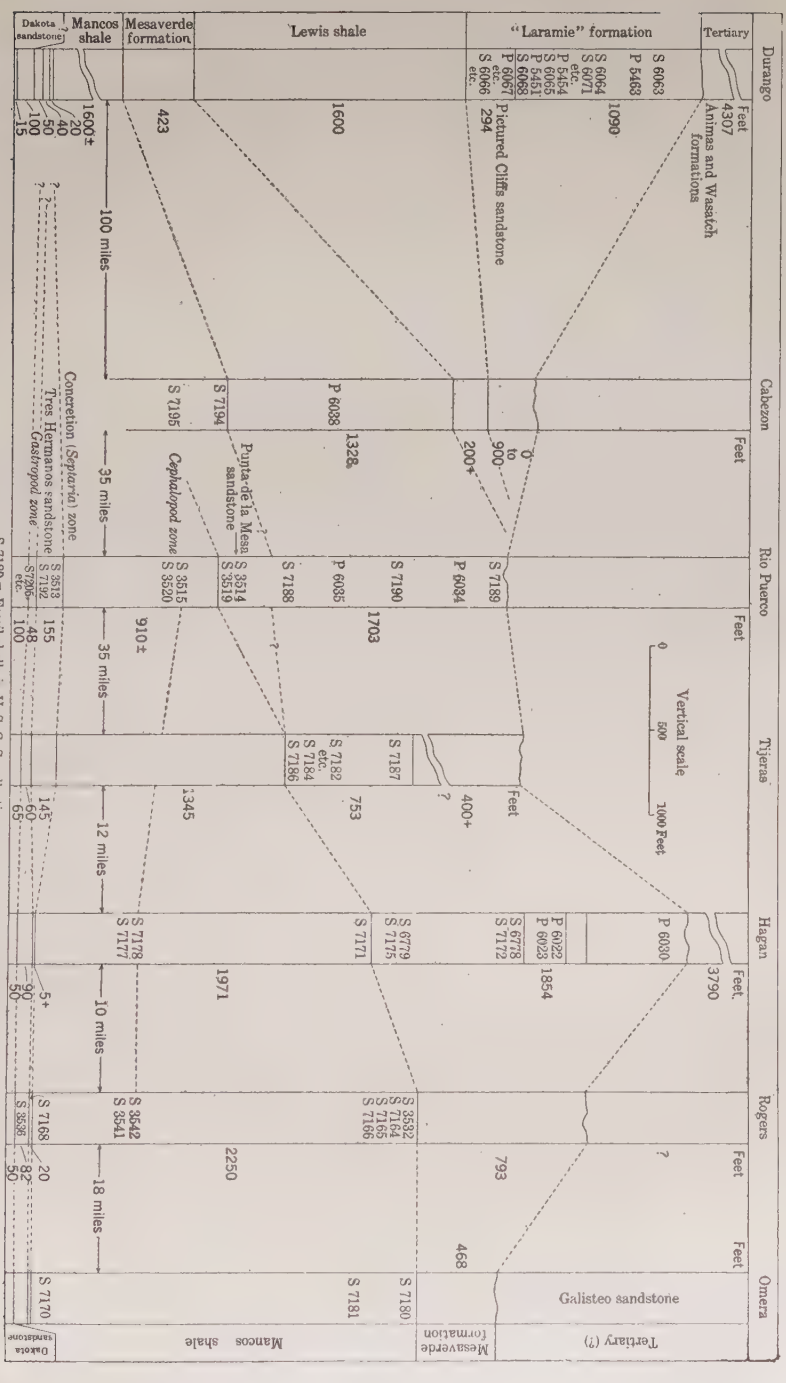

FIGURE 2.—*Correlation of Formations in New Mexico Coal Fields*

collected by the writer, T. W. Stanton makes the following statement, covering both the Mancos and the Mesaverde fauna:

"The distribution of the faunas agrees with the field determination that the coal-bearing rocks of the Cerrillos, Hagan, Tijeras, and Rio Puerco fields [also those of the Cabezon region] all belong to one formation. In the Tijeras and Rio Puerco fields the marine fauna associated with the coal occurs in rocks overlying part of the coal beds as well as immediately beneath them [as described by Mr. Lee, who collected the fossils]. This fauna is closely related to the Cretaceous faunas of the Gulf and Atlantic borders and is especially related to the fauna which occurs a short distance beneath the coal at San Carlos near the Rio Grande in western Texas. It apparently does not extend far northward, the most northern point at which it has been found being in the neighborhood of Cabezon. It is, of course, true that there are some similar and perhaps a few identical species in the Montana group faunas of Colorado and more northern areas, but the general association of forms and most of the species are entirely different. Its horizon is that of the lower part of the Montana group not far above the horizon of the Austin and the Niobrara, and hence apparently somewhat lower than the upper part of the Mancos as developed in southwestern Colorado. It is my judgment, therefore, that the base of the coal-bearing rocks in the central New Mexican fields mentioned is lower, perhaps by several hundred feet, than the base of the Mesaverde in the neighborhood of Durango, Colorado. It is worthy of note that Mr. Lee's collections show a good development of the Benton fauna in the beds underlying those containing the fauna associated with the coal, and this Benton fauna is, with some additions, essentially the same that occurs in the lower 400 feet of the Mancos shale in its type area, and also in the Benton east of the mountains in Colorado."

MESAVERDE FORMATION

The Mesaverde consists principally of sandstone, shale, and coal. It is 423 feet thick near Durango, Colorado, and about the same at Monero, New Mexico, but is very much thicker farther south. Most of the sandstone is yellow and occurs in beds, some of which are massive and thick, alternating with shale. In some places the sandstone is more or less lenticular and contains irregular masses of impure limestone with great numbers of marine invertebrates. Some of the shale also contains marine fossils. These rocks of marine origin alternate with those containing beds of coal and fossil plants.

Fossils were collected from the Mesaverde at many localities. Those collected where the sections were measured are denoted by the lot numbers, which identify them in the collections of the United States Geological Survey, and the same numbers are placed in the generalized sections, figure 2, to mark the horizons from which they came. The localities where they were collected are also indicated by the same numbers on the accompanying map. Those collected at a distance from the

Table of Distribution of Cretaceous Invertebrates from southern Colorado and northern New Mexico

Identified by T. W. Stanton

	Mancos						Mesaverde				Lewis	Pierre and Trinidad
	Lower		Upper									
	Rio Puerco	Hagan and Cerrillos	Durango	Cabezon	Rio Puerco [5]	Cerrillos	Durango	Cabezon	Rio Puerco	Hagan	Dulce	Raton
	1	2	3	4	5	6	7	8	9	10	11	12
Actæon intercalaris Meek	...	...	...	...	...	...	×	...	...	...	...	...
Actæon sp. (several undescribed species)	×	×	...	×	...	?	...	×	?	×	×	...
Acanthoceras ? sp.	×	...	...	...	...	...	...	...	...	...	...	...
Anatina sp.	...	×	...	...	...	×	...	...	...	...	...	...
Anchura fusiformis White non Meek	×	...	...	...	...	...	...	...	...	...	...	...
Anchura newberryi Meek	...	...	...	...	...	...	×	...	...	...	...	...
Anchura sp. (several species)	×	×	...	...	×	×	...	...	...	?	...	...
Ancyloceras sp.	...	...	...	...	...	...	...	...	...	...	×	×
Anisomyon patelliformis M. & H.	...	...	...	...	...	...	...	...	...	...	×	...
Anisomyon sp.	?	...	...	...	...	...	...	...	?	...	...	?
Anomia sp.	×	...	...	×	...	×	...	...	×	×	×	×
Arca sp.	×	...	?	...	...	...	...	×	..	...	...	×
Astarte sp.	...	...	...	...	...	×	...	...	...	...	...	...
Avicula gastrodes Meek	×	...	...	...	...	...	...	...	...	...	...	...
Avicula linguiformis E. & S.	...	...	...	×	...	...	...	...	...	...	...	...
Avicula sp.	...	...	...	...	...	...	...	...	×	...	...	×
Baculites anceps var. *obtusus* Meek	...	...	...	...	...	...	×	×	...	...	...	...
" *asper* Morton	...	...	?	...	...	×	...	...	...	...	...	...
" *compressus* Say	...	...	...	...	...	...	×	...	...	...	×	×
" *gracilis* Shumard	?	...	...	...	...	...	...	...	...	...	...	...
" *ovatus* Say	...	...	?	...	...	...	...	...	...	...	×	×
" sp.	...	...	×	...	...	×	...	...	×	...	...	...
Callista deweyi M. & H.	...	...	...	...	...	...	×	...	...	...	...	...
Callista pellucida	...	...	...	...	...	...	×	...	...	...	...	...
Camptonectes symmetrica Herrick & Johnson	×	...	...	...	...	...	...	...	...	...	...	...
Cardium bellulum Meek	...	...	...	...	...	...	×	...	...	...	...	...
" *speciosum* M. & H.	...	...	...	...	...	...	×	...	...	...	×	...
" sp. (several species)	×	×	...	×	×	×	...	×	×	×	...	...
" sp. (large)	...	...	...	...	...	...	...	...	×	...	...	...
" sp. (small)	...	...	...	...	...	...	...	...	×	...	...	...
Cinulia ? sp.	×	...	...	...	...	...	...	...	..	...	...	...
Coilopoceras colleti Hyatt	×	...	...	...	×	...	...	...	...	...	...	...
Corbicula sp.	...	...	...	...	...	...	×	...	..	...	...	...
Corbula sp.	×	...	...	×	...	×	..	...	×	...	...	...
Crassatellites cimarronensis White	...	...	...	...	...	...	...	...	...	...	...	×
" *shumardi* Meek	...	...	...	...	...	×	...	...	...	×	...	...
" sp.	...	×	...	?	...	...	...	...	...	...	...	...
Cucullæa sp.	...	...	...	×	...	×	..	×	×	...	...	×
Cyprimeria sp.	?	...	...	×	...	×	...	?	×	×	...	...
Dentalium sp.	...	...	...	...	...	×	×	...	×	...	...	...
Exogyra columbella Meek	×	×	...	...	...	...	...	...	×	...	...	...
" *ponderosa* Roemer	...	...	...	...	...	×	...	...	...	...	...	...

Table of Distribution of Cretaceous Invertebrates—Continued

	Mancos						Mesaverde				Lewis	Pierre and Trinidad
	Lower		Upper									
	Rio Puerco	Hagan and Cerrillos	Durango	Cabezon	Rio Puerco[5]	Cerrillos	Durango	Cabezon	Rio Puerco	Hagan	Dulce	Raton
	1	2	3	4	5	6	7	8	9	10	11	12
Exogyra sp.	...	...	...	×	...	...	...	...	...	...	...	...
Fasciolaria (*Piestochilus*) sp.	...	...	...	...	...	...	...	...	...	...	...	×
Fasciolaria sp.	...	...	...	...	...	...	×	...	...	?	...	×
Fish scales	...	...	...	...	...	...	...	...	...	...	×	...
Fish vertebræ	...	...	...	...	...	...	...	...	...	×	...	×
Fusus sp.	×	...	...	...	...	...	×	...	...	...	?	...
Gervilliopsis ? sp.	×	...	...	...	...	...	...	...	...	...	...	...
Gryphæa newberryi Stanton	?	×	...	...	×	...	...	...	...	...	...	...
Gyrodes sp.	...	×	...	×	...	×	...	×	×	×	...	...
Haminea sp.	...	...	...	...	...	...	...	...	...	...	×	...
Hamites sp.	...	...	...	...	...	×	...	...	...	...	...	...
Heteroceras cheyennense M. & H.	...	...	...	...	...	...	...	...	...	...	...	×
Heteroceras sp.	×	...	...	...	...	...	...	×	...	...	...	×
Inoceramus sp. cf. *I. acuteplicatus* Stanton	...	...	...	...	...	...	...	...	...	×	...	...
" *barabini* Morton	...	...	×	?	...	...	×	...	...	×	...	×
" sp. cf. *I. barabini* Morton	...	...	...	...	...	×	...	...	...	...	...	...
" sp. cf. *I. deformis* Meek	...	...	...	...	...	...	...	...	×	...	...	...
" *dimidius* White	...	×	...	...	...	...	...	...	...	...	...	...
" sp. cf. *I. dimidius* White	...	×	...	...	...	...	...	...	...	...	...	...
" *dimidius* var. *labiatoides* S. & B.	...	...	...	...	...	...	...	...	...	...	...	...
" *erectus* Meek	...	...	...	...	...	...	...	...	...	...	...	...
" sp. cf. *I. erectus* Meek	...	...	...	...	...	...	...	...	×	...	...	...
" *fragilis* H. & M.	×	×	...	...	...	...	...	...	...	...	...	...
" *irregularis* Johnson	...	...	...	...	...	×	...	...	...	...	...	...
" *labiatus* Schloth	...	×	...	...	...	...	...	...	...	...	...	...
" *oblongus* Meek	...	...	...	...	...	...	...	...	...	...	?	×
" *sayensis* Owen	...	...	×	...	...	×	...	...	...	...	×	×
" *vanuxemi* M. & H.	...	...	...	...	...	...	...	...	...	...	...	×
" sp. cf. *I. proximus* Tuomey	...	...	...	...	...	×	...	...	...	...	...	...
" sp.	×	...	×	...	...	×	...	...	×	×	...	×
Isocardia sp.	×	×	...	...	×	...	...	...	...	...	...	...
Lamna sp. (shark's teeth)	...	...	...	×	...	...	...	...	×	×	...	...
Leda sp.	×	...	...	...	...	×	×	...	...	×	...	×
Legumen sp. cf. *L. planulatum* Conrad	...	...	...	...	...	...	...	...	...	×	...	...
Legumen sp.	×	...	...	...	...	?	...	...	...	...	...	?
Liopeplum sp.	...	...	...	×	...	×	...	...	...	...	...	...
Lima sp.	...	×	...	...	...	...	...	...	...	...	...	×
Liopistha (*Cymella*) *undata* M. & H.	...	...	...	?	...	×	...	×	?	×	?	×
" (*Psilomya*) sp.	×	...	...	...	...	...	...	...	...	...	...	...
" (") *concentrica* Stanton	×	...	...	...	...	...	...	...	...	...	...	...
Lithophagus sp.	...	...	...	...	...	...	...	...	?	×	...	...
Lucina occidentalis (Morton)	...	...	...	...	...	...	...	...	...	...	×	×
Lucina sp.	×	...	...	...	...	...	×	...	...	...	...	×
Lunatia concinna (H. & M.)	...	...	...	...	...	...	...	...	...	...	...	...

Table of Distribution of Cretaceous Invertebrates—Continued

	Mancos						Mesaverde				Lewis	Pierre and Trinidad
	Lower		Upper									
	Rio Puerco	Hagan and Cerrillos	Durango	Cabezon	Rio Puerco[5]	Cerrillos	Durango	Cabezon	Rio Puerco	Hagan	Dulce	Raton
	1	2	3	4	5	6	7	8	9	10	11	12
Lunatia sp.	×						×			×	×	×
Mactra alta M. and H.							×					
Mactra sp. cf. *M. formosa* M. & H.				×					×	×		
" sp. cf. *M. gracilis* M. & H.										×		
" *warrenana* M. & H.												×
" sp. (large form)									×			
" sp.		×				×		×	×	×	?	×
Martesia ? sp.												×
Metoicoceras sp. cf. *swallovi* (Shumard)					×							
Metoicoceras sp.	×				×							
Modiola sp.										×	×	
Mortoniceras sp. cf. *M. delawarense* (Morton)						×						
Mosasaurus sp.												×
Mytilus sp.				×						?		×
Nautilus dekayi Morton						×						
Nautilus sp.						×						
Nemodon sp.												×
Nucula sp.						×		×				×
Odontobasis sp.							×					?
Odontofusus ? sp.										×		
Ostrea congesta Conrad									×			
" *elegantula* Newb.				?		?				×		
" *inornata*							×					
" *lugubris* Conrad	×	×			×							
" sp. cf. *O. lugubris* Conrad		×								×		
" *patina* M. & H.												×
" *pellucida* M. & H.							×				?	
" *subtrigonalis* E. & S.							×					
" (*Alectryonia*) sp.										×		
" sp.	×	×				×			×	×	×	×
Pachydiscus n. sp.		×										
Panopæa sp.	×						×					?
Pectem sp.	×	×			×							
Pholadomya sp.	×	×										
Physa ? sp.									×			
Pinna lakesi White											?	
Pinna petrina White	×	×			×							
Pinna sp.	×	×		×			×			×		
Placenticeras intercalare M. & H.							×				×	×
" *planum* Hyatt						×			×	×		
" *sancarlosense* Hyatt				?		×		×	?	×		
" *whitfieldi* Hyatt											×	×
" sp.		×				×		×				×
" sp. (large form)						×						
Plicatula sp.	×	×										
Prionocyclus wyomingensis Meek	×	×										

Table of Distribution of Cretaceous Invertebrates—Continued

	Mancos						Mesaverde				Lewis	Pierre and Trinidad
	Lower		Upper									
	Rio Puerco	Hagan and Cerrillos	Durango	Cabezon	Rio Puerco [5]	Cerrillos	Durango	Cabezon	Rio Puerco	Hagan	Dulce	Raton
	1	2	3	4	5	6	7	8	9	10	11	12
Prionotropis woolgari Mantell	...	?	...	...	...	...	...	...	...	...	...	...
" sp.	×	×	...	...	...	...	...	...	...	...	...	...
" sp.	...	×	...	...	...	...	...	...	...	...	...	...
Pterocerella sp.	...	...	...	...	...	...	...	...	...	×	...	...
Ptychodus sp. (fish teeth)	×	...	...	...	...	...	...	...	...	...	...	...
Ptychoceras sp.	...	...	...	...	...	...	...	...	...	...	...	×
Pyrifusus sp.	...	...	...	?	...	...	...	?	...	?	×	×
Pyropsis sp.	...	...	...	...	...	...	...	...	×	?	...	...
Scaphites sp. cf. *S. hippocrepis* Dekay	...	...	...	...	...	×	...	...	...	×	...	...
" " " " *larvæformis* M. & H.	...	...	...	×	...	...	...	...	...	...	...	...
" *nodosus* Owen	...	...	...	...	...	...	...	...	...	...	×	×
" sp. cf. *S. nodosus* Owen	...	...	...	...	...	...	...	...	×	...	...	...
" *warreni* M. & H.	×	×	...	...	...	...	...	...	...	...	...	...
" sp.	...	...	×	...	...	...	...	...	...	...	...	×
Serpula sp.	×	...	...	...	...	...	×	...	...	...	...	...
Sphæriola sp.	...	...	...	...	...	...	×	...	...	...	...	?
Stantonoceras pseudocostatum Johnson	...	...	...	?	...	×	...	...	...	...	...	...
Syncyclonema rigida H. & M.	...	...	×	...	...	...	...	...	...	...	×	...
Syncyclonema sp.	...	...	...	...	...	...	...	...	...	×	×	×
Tellina scitula M. & H.	...	...	...	...	...	...	...	...	...	...	...	×
" ? sp.	...	...	...	...	...	...	...	...	...	...	...	×
" sp.	...	...	...	×	...	...	...	...	×	×	×	×
Thetis circularis M. & H.	...	...	...	...	...	...	...	...	...	...	×	...
Trigonarca (Breviarca) exigua M. & H.	...	...	...	...	...	...	...	...	...	...	×	...
" sp.	×	...	...	...	×	...	...	...	...	...	...	...
Tritonium kanabense Stanton	×	...	...	...	...	...	...	...	...	...	...	...
Turris sp.	...	...	...	...	...	...	...	...	...	×	...	...
Turritella galistcoensis Johnson	...	...	...	...	...	×	...	...	...	...	...	...
" sp. cf. *T. whitei* Stanton	×	×	...	...	...	...	...	...	...	...	...	...
" sp. (probably several species)	×	×	×	...	×	...	×	...	...	×	...	...
Veniella sp.	×	...	...	...	?	...	...	...	...	...	...	...
Volutoderma dalli (Stanton)	...	×	...	...	...	...	...	...	...	...	...	...
Volutoderma sp.	...	?	...	?	×	?	...	×	...	?	...	×
Volutomorpha novomexicana Herrick & Johnson	...	...	...	...	...	...	...	...	×	×	...	...
Volutomorpha sp.	...	×	...	×	...	...	...	...	...	...	...	...

[5] The upper part of the Mancos in the Rio Puerco field yields the same fauna as that of the lower part of the Mancos farther east. In order to show the differences in age, the column denoting upper Mancos in the Rio Puerco field is placed next to that denoting upper Mancos in the Cerrillos field.

measured sections are described apart from the sections. The species of each lot are named in the descriptions of the several fields given in the latter part of this paper, and the general grouping of them is presented in the preceding table. This table contains only the names of fossils identified by T. W. Stanton from collections made principally by the writer, although a few fossils collected by J. H. Gardner and others in western Colorado and New Mexico have been included. Relatively few of these species have ever been described. This may be of no serious consequence for the purposes of this paper, inasmuch as these species seem to have a somewhat restricted geographical distribution in New Mexico, and their nearest known allies occur far to the southeast in Texas; but it is unfortunate that so well developed a fauna as that shown in the foregoing table can not now be made available by proper descriptions and illustrations for purposes of correlation as stratigraphic work is extended in the coal fields of New Mexico. A few of the species have been described by Herrick and Johnson and by Shimer and Blodgett, and the names given them will be found in the annotated list of publications in the latter part of this paper, but only those species which have been identified in the collections of the United States Geological Survey are included in the table.

Fossil plants occur at certain horizons in the Mesaverde of all the coal fields in central New Mexico, and in some places they are numerous and well preserved, but fossil plants seem to be rare in the Mesaverde of northern New Mexico and southern Colorado. Unfortunately, a large part of the flora consists of undescribed species, so that the lack of specific names in the following table might be interpreted as indicative of poor material, whereas in reality it indicates undescribed species of beautifully preserved leaves. Unlike the invertebrates, whose nearest allies occur far to the south, some of the fossil plants are specifically identical with those from some of the coal fields to the north and east, and others are so strikingly similar to species found in those fields that they indicate essentially the same age. Thus the flora most nearly like that of the Mesaverde of central New Mexico is found at Point of Rocks, Wyoming, and other localities to the north in rocks of recognized Montana age. The correlation with the older coal-bearing formation of the Raton field is nearly as perfect, but since the flora of the Raton field is being critically studied at the time of this writing, no final statement regarding the correlation can be made. However, Doctor Knowlton, who has identified the fossils listed in the following table and who is studying the flora of the Raton field, has kindly made the following statement for use in this paper:

"The fossil plant material from the coal fields of central New Mexico while very extensive is not yet fully worked up—in fact is largely new to science—which accounts for the short lists of species. However, it is not probable that any material change of opinion is as regards stratigraphic position is likely to result from the complete elaboration of the material, but rather it is likely to be strengthened by the recognition of a greater number of species common to the various areas.

"Bearing in mind the above limitations, we may first consider the flora of the Raton Mesa region which occurs in association with the lower coal; that is, in the beds below the now well established unconformity. If, as has been suggested, the beds immediately below the Trinidad sandstone are to be correlated with the Lewis shale of the San Juan Basin, then the overlying coal-bearing rocks might on stratigraphic grounds be presumed to belong to the Laramie. The plants found in these beds do not bear out this contention, for they have almost no affinity with the typical Laramie of the Denver Basin, there being only two or three species in common, and these of wide vertical distribution or of doubtful identification. On the other hand, this flora has a positive and unmistakable affinity with the flora of the Mesaverde of the western slope of the mountains, and, to go further afield, with the flora of the Rock Springs coal group (Mesaverde) of Point of Rocks, Wyoming. When we find, as is the case, that such well-marked and hence unmistakable species as *Sequoia brevifolia*, *Woodwardia crenata*, *Ficus speciosissima*, *Ficus 'trinervis,'* *Ficus wardii*, *Ficus lanceolata*, *Sabal 'grandifolia'* (Geonomites of some writers), *Myrica torreyi*, as well as a number of equally well-marked but unnamed species, in common between this and one or the other of the areas above mentioned, we are inevitably led to the conclusion that they are essentially of the same age.

"On the west side of the mountains in the Cerrillos, Hagan, Tijeras, Rio Puerco, and Cabezon coal fields, the floras under discussion occur mainly in the coal-bearing beds from 400 to 600 feet above the base of the Mesaverde of this region, though some of them also range somewhat higher in the Montana, especially in the Durango field to the north. The relationship between these floras and that at Point of Rocks, Wyoming, is even closer than that already mentioned between the Raton Mesa region and Point of Rocks, by the addition of such forms as *Nelumbo intermedia*, *Trapa microplylla*, *Salix Stantoni?*, etcetera. There can be no doubt, it seems to me, that the floras of the Raton Mesa region, of the central and western New Mexican fields and of the Point of Rocks field, are essentially identical, and hence, *per force*, are of essentially the same age.

"Near Dulce, New Mexico, and near Durango, Colorado, there have been obtained two collections of plants from above the Lewis shale in coal-bearing rocks that have been referred to the so-called 'Laramie' of this region. These collections are very full and embrace a number of easily recognized species—hence their identification is satisfactory and complete. These collections prove clearly that these beds do not belong to the Laramie, since so far as known to the writer, not a single species there present has ever been found in beds of this age. On the other hand, the plants indicate beyond question that they belong to the Montana, there being, for instance, *Ficus speciosissima*, *Ficus* sp. (narrow 3-nerved type), *Ficus* sp. type of *F. lanceolata*, a palm, etcetera,

which link them with the Mesaverde floras to the south and the beds already discussed in the Raton Mesa region. Associated with these, however, and tending to give them a slightly higher position, although still within the Montana, are such forms as *Brachyophyllum, Cunninghamites, Geinitzia, Sequoia,* etcetera, all of which are beyond doubt Montana types never found in the Laramie.

"A number of collections were made by J. H. Gardner in the Ignacio Quadrangle, east of Durango, Colorado, from beds regarded as the 'Laramie' of that area. The plants in these collections, almost species by species, are identical with the forms from Dulce and near Durango, and I have no hesitation in saying that they occupy the same stratigraphic position and are the same in age, viz., Montana."

The Lower Montana age of the principal coal-bearing formation, indicated by the fossil shells, has already been stated in the quotation from Doctor Stanton. The fossil leaves indicate the same age, although some of the species occur at Coalville, Utah, in rocks generally regarded as older than Mesaverde, and others in the so-called "Laramie" above the Lewis shale.

An effort was made to correlate the coal-bearing rocks of central New Mexico with the Mesaverde formation of southwest Colorado, where this formation was originally named. Mr. Schrader traced the typical Mesaverde from Durango eastward and southward around the San Juan Basin, but he was not satisfied that the coal-bearing rocks near Cabezon are to be correlated directly with the typical Mesaverde and he described them as the "Lower Montana group; relation to Mesaverde unknown." However, Doctor Gardner, who later examined the same rocks, referred them definitely to the Mesaverde (110, 115, 116).

The present writer visited the Durango region for the purpose principally of examining the rocks originally named Mesaverde. It was thought that this region would be favorable for the collection of fossil plants, inasmuch as the Mesaverde coal has been extensively mined there. He also examined the coal-bearing formation at Monero, New Mexico, and was convinced, as others have been, that it is equivalent to the Mesaverde of the Durango region. However, it was noted that the Mesaverde at Monero is only a few hundred feet thick, probably about the same as in the Durango region, where it is only 423 feet, while the Mesaverde of Doctor Gardner's Arroyo Torreons section (116, page 178), measured a few miles northwest of Cabezon, is more than 1,300 feet thick. A somewhat hasty examination of the rocks between Monero and Cabezon convince the writer that the base of the Mesaverde as described by Schrader and Gardner is essentially the same at both localities, and that the upper part of it near Cabezon is probably equivalent in age to the lower part of

Table showing the Distribution of Fossil Plants from central and western New Mexico and southwestern Colorado

(The locations of the principal lots are indicated on the accompanying map by means of the locality numbers)

Identified by F. H. Knowlton

	Cerrillos field				Hagan field						Tijeras	Rio Puerco field				Cabezon	Monero	Dulce	Durango
																San Juan Basin			
United States Geological Survey locality numbers	6017	6018	6019	6021	6022	6023	6024	6025	6026	6028	6030	6032	6034	6035	6036	6037	6038	6039	6041	6042	6043	6044	6046	6048
Alga					×																			
Abietites dubius Lesq.																								
Aralia ? sp.																								
Brachyphyllum macrocarpum Newb.																								
Brachyphyllum sp.						×						?						×						
Carpites n. sp.																								
Celastrus n. sp.					×																			
Cunninghamites sp. ?																								
Cyperacites sp.																								
Dalbergia n. sp.					×																			
Diospyros sp.														×										
Dombeyopsis ? sp.																								
Dryophyllum falcatum Ward.														×										
Dryopteris n. sp.																								
Ficus lanceolata Heer				×	×		×	×	×													×		×
" *planicostata* Lesq.								×																
" *rhamnoides* Kn.			×																					
" *speciosissima* Ward.			?				?	×								?	×							
" *trinervis* Kn.																						×		
" *uncata* Lesq.			×																					
" cf. *F. Wardii* Kn.										×														
" n. sp. (3-nerved)													?	×			×							
" n. sp.										×							×							
" sp.											×		?	×								×		
Equisetum sp.																								
Eucalyptus sp.																								
Geinitzia formosa Heer																	×							
" sp.	×																		×					
Geonomites sp.			×																			×		
Gleichenia sp.					?																			
Laurus ? sp.																								
Myrica Torreyi ? Lesq.												×												
" sp.												×												
" ? n. sp.																								
Nelumbo intermedia ? Kn.																								
Palmocarpon commune ? Lesq.			×																					
Protophyllocladus sp.						×																		
Quercus sp.			?																					
" n. sp.																								
Salix stantoni ? Kn.					×																			
" ? sp.														×										
Sequoia reichenbachi (Gein) Heer.													×											
Trapa ? *microphylla* Lesq.					×																			
Typha sp.																								
Viburnum ? *problematicum* Kn.																								
" sp.																								
Zizyphus n. sp.										×														

the Lewis as developed near Monero. The coal-bearing formation of the Rio Puerco field is essentially equivalent to the Mesaverde of the San Juan Basin, but includes at its base rocks equivalent in age to the upper part of the Mancos shale. It may be stated in brief that, except for the

variations previously noted in the upper and lower limits of the formation, the coal-bearing rocks of all of the fields described in the Rio Grande Valley are lithologically, stratigraphically, faunally, and florally identical with the Mesaverde of the San Juan Basin.

LEWIS SHALE

The Lewis shale is known to occur in the region described in this paper only in the San Juan Basin. It is 1,600 feet thick near Durango, on the northern rim of this basin, and possibly thicker in some other places. According to Mr. Schrader (100, page 242), its maximum thickness is 2,500 feet. It thins rapidly southward, and at its outcrop, in the southern portions of the basin, is about 200 feet thick (116, page 171). Doctor Gardner states (110) that it is 2,000 feet thick near Gallina, but that in Arroyo Torreons, about 30 miles southwest of Gallina, it is only 250 feet thick. No explanation of this great variation in thickness can be given, but the suggestion previously noted seems pertinent that the Lewis may become sandy and coal-bearing to the south, and thus be equivalent in age to the upper portion of the Mesaverde of the Cabezon region. In this connection it may be noted that a shale of marine origin nearly twice as thick as the Lewis of the Arroyo Torreons section occurs in the midst of the Mesaverde in the Rio Puerco field, and that a sandy shale of marine origin of nearly the same thickness occurs in the Tijeras field above the principal group of coals. Because the fossils from these shales do not differ notably from those of the coal-bearing rocks above and below them, the shales are regarded as probably parts of the Mesaverde formation. However, it is entirely possible that when the faunas and floras of this region are better known some of the rocks here described as Mesaverde may prove to be equivalent in age to a part of the Lewis shale.

Few fossils have hitherto been collected from the Lewis shale of the southwest. *Baculites asper* (73, page 5) was found in it in southwest Colorado, and Doctor Gardner found a few fossil shells in it southeast of Raton Springs (locality number 4455 of the accompanying map). These, together with the shells collected by the present writer near Dulce (localities numbers 7200 and 7201), seem to make rather definite the correlation of the Lewis shale with the top of the Pierre of the Raton coal field, east of the Rocky Mountains. The fossils are named and their relation to those collected in the Raton field indicated in the table of invertebrates previously given.

"LARAMIE" FORMATION

The "Laramie" formation occurs within the area described in this paper only in the San Juan Basin. It is more than 1,000 feet thick near

Durango and nearly as thick in the southern rim of the basin (110, page 338), but is thinner in the eastern rim, probably due to the post-Cretaceous erosion. At Dulce it is only 225 feet thick. This formation lies conformably on Lewis shale, and probably for this reason more than for any other has been called Laramie, although Doctor Cross (75, page 4) several years ago called attention to the fact that investigation had "failed to bring to light valid ground for assigning any of the beds in question to the Laramie, while there is some reason to believe that more than the lower sandstone belongs to the Montana group." Since that time a considerable number of fossils, both of invertebrates and of plants, have been collected from these beds in the Durango region. The base of the formation—the Pictured Cliffs sandstone—contains marine invertebrates, and the lower part of the coal-bearing rocks above this sandstone contains brackish-water invertebrates, several of which occur in the Mesaverde of other fields. But higher in the formation the rocks contain fresh-water invertebrates which Doctor Stanton regards as Laramie and fossil plants which Doctor Knowlton regards as older than Laramie. The fossil plants have been included in the table previously given (page 606), and from this table, as well as from the accompanying statement by Doctor Knowlton, it will be seen that the flora differs but little from that of the Mesaverde farther to the south.

The name "Laramie" is here used for this formation not because the writer wishes to argue for the Laramie age of the rocks, but because the name is in use and because in this paper the writer is intentionally avoiding the introduction of new names for rock formations. It must be noted, however, that while the formation is called "Laramie" it contains a flora which denotes Montana age, having nothing in common with the Laramie flora of the Denver Basin.

Whether the formation will eventually be called Laramie or be designated in some other way depends largely on the final use of that somewhat migratory name. But in view of the fact that many of the species of marine and brackish-water invertebrates from the lower part of the formation occur in the Mesaverde of other localities; that the invertebrates from the upper part are of fresh-water origin and admittedly unreliable for purposes of correlation, and that the plants are of Montana types, serious doubt is cast on the Laramie age of the formation.

TERTIARY AND LATER FORMATIONS

It is not the purpose of the writer to enter into a discussion of the Tertiary and later formations of New Mexico farther than is necessary to show that in all of the coal fields described rocks of probable Tertiary age lie unconformably on "Laramie" or older rocks. In the Durango

region the "Laramie" is succeeded unconformably by the Animas formation, which has been regarded generally as the time equivalent of the Denver. Some geologists still refer these formations to the Cretaceous, but G. B. Richardson (122) has recently shown in a manner rather convincing to many geologists that the Denver formation is of Tertiary age. He referred the Dawson arkose to the Eocene, and since, according to Doctor Knowlton, the "leaves from the lower part of the Dawson . . . are undoubtedly Denver in age," the Denver must of necessity be of the same age as the Dawson, namely, Eocene. Rocks that seem to be equivalent in age to the Animas rest unconformably on the "Laramie" near Dulce, New Mexico, and farther to the south in the San Juan Basin the oldest Tertiary rocks—the Puerco formation—lie unconformably on the "Laramie" in some places and on the Lewis shale in other places (117).

In the Rio Puerco field rocks that are lithologically similar to the Wasatch of the San Juan Basin rest unconformably on the Mesaverde. They are varicolored, with yellow, pink, and red shales predominating, and although they have never been measured they are comparable in thickness to the Tertiary formations of that basin. These rocks consist of poorly consolidated sandstone, conglomerate, and shale. The upper part is light colored and seems to be referable to the Sana Fe marls, the type locality of which is a few miles east of the Rio Puerco field.

No rocks referable to the Tertiary were found in the Tijeras field, but in the Hagan field a series of beds comparable in thickness, lithologic character, and general appearance to the Tertiary of the Rio Puerco field rest unconformably on the Mesaverde. These beds contain great quantities of petrified wood, but no fossils were found in them that make possible the determination of their age. The Hagan and Rio Puerco fields are only about 30 miles apart, and it is difficult to believe that the rocks of these two fields, which are comparable in every other way, differ in age to any great extent.

In the Cerrillos field rocks that are lithologically similar to the Tertiary rocks of the Hagan and Rio Puerco fields and of the San Juan Basin lie unconformably on the Mesaverde. This is known as the Galisteo sandstone. The lower part of this formation consists of conglomeratic sandstone and shale identical in character and appearance to those of the Hagan field 10 miles to the west, but the upper parts are coarser and contain large angular blocks of many kinds of rock, including quartzite, and crystalline rocks such as are now exposed in the mountains a few miles to the northeast; limestone, containing Carboniferous fossils, sandstone, etcetera. Rock formations, from which these were probably derived, are now found upturned and eroded on the flanks of the mountains. The Galisteo sandstone is many hundreds of feet in thickness and

may include more than one formation, but it has not been studied with a view to subdividing it into formations or of making exact correlations with formations of other fields. These rocks are the so-called "Cretaceous red beds" of the Cerillos region, which some geologists have correlated with the Denver formation. Hayden (19), who named this formation, regarded it as Tertiary and correlated it with the Monument Creek of the Denver region, the lower part of which has recently been named the Dawson arkose (122) and correlated with the Arapahoe and Denver formations. J. J. Stevenson (53) failed to separate the Galisteo from the underlying coal measures and referred both formations to the Laramie. D. W. Johnson (83) also failed to recognize the unconformity at the base and included the lower part of the Galisteo sandstone in his Madrid group, which he referred to the Fox Hills. He referred the upper part to the Laramie. Nothing has been found in the Galisteo to establish its geologic age. It contains great numbers of petrified logs, which are beautifully preserved in external form, but the cellular structure of the wood is not well preserved and no specific identifications have been made. The best known locality at which these logs occur is a few miles east of Cerrillos, in the so-called petrified forest, where there are many logs 25 to 75 feet or more in length. But logs have been found in this formation in many other places in a state of preservation much better than that of the logs near Cerrillos. Fossil leaves have also been found in a few places, but their preservation is poor and few have been specifically identified. All things considered, it is probable that the Galisteo sandstone should be correlated with those Tertiary formations farther west that are similar to it in character and stratigraphic position. This relation is indicated by the correlation lines in figure 2, page 597.

Correlation with the Raton Section

The Raton coal field is located in northern New Mexico, east of the Rocky Mountains, and is separated from the San Juan Basin by a mountainous area about 90 miles wide. The Cretaceous and younger formations of this field were described three years ago by the writer (111) as consisting of Dakota sandstone, a shale equivalent in age to Benton, Niobrara, and Pierre; the Trinidad sandstone, a coal-bearing formation called "Laramie or older (?)," and a younger coal-bearing formation of post-Laramie age lying unconformably on the older one. Up to that time these coal-bearing formations had been grouped together under the name Laramie. Two years later the writer (119) traced them around the Raton and Trinidad coal fields and found them unconformable in all parts of the Raton Mesa region. During the later investigation a large

volume of data was obtained which is not yet ready for publication. Great numbers of fossil plants were collected from both coal-bearing formations, and a special study of them is being made by F. H. Knowlton. Although his study is not complete, it has progressed so far that he feels justified in stating definitely that the plants from the two formations constitute two distinct floras; that the upper one is post-Laramie in age, and that the lower one, formerly (111) called "Laramie or older (?)," is clearly Montana and older than recognized Laramie. Inasmuch as the study of these floras is incomplete, it is thought best to withhold the lists of species. The rock formations of this field and their relations to each other are shown in the following section:

Generalized Section of Rocks in the Raton Coal Field, New Mexico

	Feet
Sandstone and shale, conglomeratic at the base, coal-bearing, containing fossil plants of post-Laramie age	1,600±
(Unconformity.)	
Sandstone and shale, coal-bearing, containing fossil plants which Knowlton regards as older than Laramie	0–475
Sandstone (Trinidad) containing *Anomia*? sp.; fish bones; *Halymenites major* Lesq.; *Inoceramus barabini* Morton; *Inoceramus sagensis* Owen; *Inoceramus* sp.; *Legumen?* sp.; *Mactra warrenana* M. and H.; *Mactra*? sp.; *Mytilus*? sp.; *Panopæa*? sp.; *Tellina scitula* M. and H.; *Tellina* sp.	100±
Shale with concretions and thin layers of limestone. Near the top the shale contains the following Pierre fossils: *Ancyloceras* sp.; *Anisomyon?* sp.; *Anomia* sp.; *Arca* sp.; *Avicula* sp.; *Baculites ovatus* Say; *Baculites compressus* Say; *Crassatellites cimarronensis* White; *Fasciolaria (Piestochilus)* sp.; *Fasciolaria* sp.; *Heteroceras cheyensis* M. and H.; *Heteroceras* sp.; *Inoceramus barabini* Morton; *Inoceramus oblongus* Meek; *Inoceramus sagensis* Owen; *Inoceramus vanuxemi* M. and H.; *Inoceramus* sp.; *Leda* sp.; *Lima* sp.; *Liopistha* (Cymella) *undata* M. and H.; *Lucina occidentalis* (Morton)?; *Lucina* sp.; *Lunatia* sp.; *Mactra* sp.; *Martesia*? sp.; *Mosasaur* bones; *Nautilus dekayi* Morton; *Nemodon* sp.; *Odontobasis*? sp.; *Ostrea patina* M. and H.; *Ostrea* sp.; *Placenticeras intercalare* M. and H.; *Placenticeras whitfieldi* Hyatt?; *Placenticeras* sp.; *Ptychoceras* sp.; *Pyrifusus?* sp.; *Scaphites nodosus* Owen; *Scaphites* sp.; *Syncyclonema* sp. The lower part of the shale contains Benton and Niobrara fossils. The following were collected in the Raton field: *Baculites asper* Morton; *Coilopoceras novimexicanum* Hyatt; *Inoceramus dimidius* White; *Inoceramus fragilis* H. and M.?; *Inoceramus labiatus* Schlotheim; *Inoceramus* sp.; *Ostrea lugubris* Conrad; *Ostrea* sp.; *Prionocyclus wyomingensis* Meek; *Scaphites ventricosus* M. and H.	3,000±
Sandstone (Dakota).	
Total	5,175

The lower part of the shale overlying the Dakota sandstone is clearly of Benton age, and Niobrara is probably also represented, although these formations are not so clearly separable as they are in southern Colorado. The upper part of the shale contains a Pierre fauna, but it is not certain that this fauna is indicative of latest Pierre time. On the other hand, it contains a fauna very similar to that of the Lewis shale at Dulce on the opposite side of the mountains. If it be assumed that the highest coal-bearing rocks at Dulce are of Laramie age, the correlation would make the top of the Pierre of the Raton field and the top of the Lewis at Dulce equivalent to highest Montana and tend to place the lower coal group of the Raton field in the Laramie; but the fossil plants above the marine rocks at both localities indicate Montana rather than Laramie age. It is, therefore, probable that the shale does not at either locality represent latest Montana time.

Some geologists have referred the Trinidad sandstone to the Fox Hills, but no unquestioned Fox Hills is known south of Colorado Springs. The fossils of the Trinidad, named in the foregoing section, belong to the Montana fauna, but are not of distinctive Fox Hills species. This fact indicates that the Trinidad may be equivalent in age to some part of the Pierre of other localities, and that Fox Hills time may be represented by something younger than Trinidad, perhaps in part by rocks that were entirely removed during the post-Cretaceous erosion. The flora of the lower coal measures, described as Montana in age and similar to that of the Mesaverde of the central New Mexico fields, resembles in a lesser degree the flora of the so-called "Laramie" of southwest Colorado and northwest New Mexico—a flora which Doctor Knowlton maintains is "Montana and not Laramie." The evidence seems to indicate that the coal measures below the unconformity in the Raton field belong in the Montana somewhere between the Mesaverde of the central New Mexico fields and the so-called "Laramie" of northwestern New Mexico.

Post-Cretaceous Unconformity

Evidence has previously been presented (111 and 119) to prove that the unconformity in the Raton field is equivalent in time to the post-Laramie unconformity of the Denver Basin, and that the erosion represented by it was comparable in amount in the two regions. The youngest rocks left in the Raton field by this erosion are the Montana coal measures. If younger Cretaceous formations ever existed there, they were eroded away. The formation next above the unconformity is correlated by fossils as well as by stratigraphic position with the Arapahoe and Denver formations.

In the Cerrillos and Hagan fields, which may be considered together, inasmuch as they are separated only on account of faulting, the unconformity is probably equivalent in time to that in the fields just mentioned. It separates rocks of Montana age—the Mesaverde—from those which have been correlated with the Denver formation and which are shown in this paper to be probably equivalent to the Tertiary formations of the San Juan Basin. The interval of erosion was comparable in duration to that of the Raton and the Denver regions, inasmuch as the older sedimentary rocks in the mountains were eroded down to the ancient crystallines, as is shown by the presence in beds immediately above the unconformity of pebbles of all of these rocks.

In the Rio Puerco field also the unconformity separates the Mesaverde formation from rocks of Tertiary age, and a few miles farther north, in the vicinity of Cuba, Tertiary rocks that are lithologically the same as those of the Rio Puerco field lie unconformably on Mesaverde and older rocks and also on the Lewis shale and the "Laramie" formations. Farther north at Dulce the Tertiary rocks lie unconformably on the "Laramie." The relations of the Tertiary to the older rocks in the several fields described in this paper are indicated in figure 2, and the relations of the formations near Dulce to those of the Raton field and to the intervening mountains are shown in the sketch section, figure 3.

The possible objection to the postulate that the unconformities in all these fields have not been proved to be exact time equivalents may be met by the equally valid argument that there is no proof to the contrary. In no place do rocks younger than Cretaceous occur below the unconformity, nor do any rocks of undoubted Cretaceous age occur above it. From a diastrophic viewpoint, this unconformity is the logical plane of separation between the Cretaceous and the Tertiary in the Rocky Mountain region. The same plain of separation is indicated by the fossil plants. Those below the unconformity in all of the fields described belong to the Montana flora, while those above it are of Tertiary types.

The correlation of the unconformities in the various fields is based largely on a broad conception of the physical conditions existing in the Rocky Mountain region during late Cretaceous time. This is too large a subject to be discussed here, but it is generally agreed by geologists that in early Cretaceous time the area now occupied by the Rocky Mountains was one of very low relief if not actually baseleveled. It is not improbable that the Cretaceous formations once extended over much if not the entire area now occupied by the Rocky Mountains. This conception is wholly in agreement with the observed relations in New Mexico. The Cretaceous formations are comparable in thickness and in lithologic char-

acter on either side of the mountains and sediments above the Dakota sandstone, varying in thickness from 1,000 to more than 2,000 feet, give little indicaton that they were derived from a land-mass in the Rocky Mountain area rather than from land-masses at greater distances. Inasmuch as the remnants of them are now separated by a distance of less than 90 miles, as shown in figure 3, it seems reasonable to assume that they once extended continuously over the area now occupied by the mountains. Although minor warpings of the surface may have occurred, causing differences in the thickness of these sediments, or even causing slight emergencies in some places, there seems to have been no orogenic disturbance in the mountain region before the close of the Cretaceous which left any unmistakable imprint on the stratigraphic record. At the close of the Cretaceous the first great upheaval of the mountains occurred and erosion naturally began on all sides of them. It is recorded on the east, south, and west sides by the post-Cretaceous unconformity described in this paper. The period of erosion was sufficiently long to remove thousands of feet of consolidated rock, and doubtless the sediments thus derived accumulated in formations that are transitional in time between Cretaceous and Tertiary. Such formations should be found at a distance from the mountains, while those above the unconformity near the mountains should represent time somewhat later than the beginning of the Tertiary.

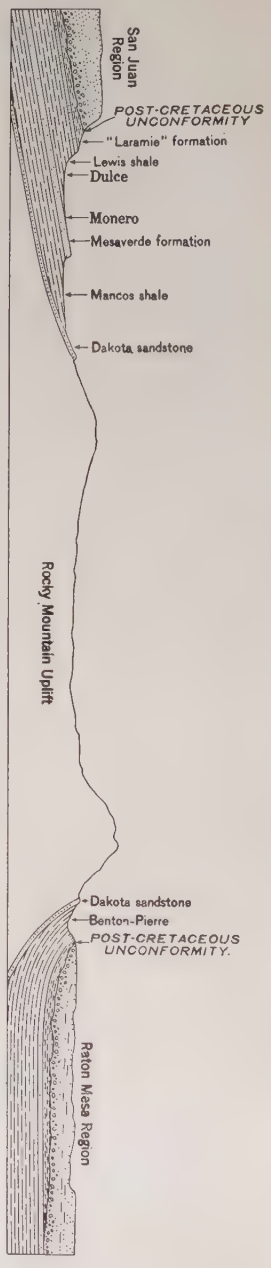

FIGURE 3.—*Sketch Section through the Raton Mesa and San Juan River Regions*

The area is near the boundary between Colorado and New Mexico, and the sketch section shows the occurrence of a post-Cretaceous unconformity on either side of the Rocky Mountains.

Descriptive Details

MONERO AND DULCE

The details noted in the Durango region have been given in the description of the type section. The next place east of Durango in which the writer made observations is between Chama and Dulce, on the Denver and Rio Grande Railroad, in northern New Mexico. Here the Dakota sandstone was observed in a small canyon about 2 miles southeast of Chama. The Mancos shale occupies a broad valley between Chama and Monero, and near its base is a sandy zone, which represents in a general way the Tres Hermanos sandstone typically developed farther south. The writer collected no fossils from the Mancos in northern New Mexico, but Schrader obtained *Inoceramus fragilis* H. & M., *Scaphites warreni* M. & H., and *Prionocyclus wyomingensis* Meek from a locality on Chama River 2 miles northwest of Elvado, New Mexico, at a horizon estimated by him to be about the middle of this shale. According to Doctor Stanton, these fossils denote Upper Benton age.

Just east of Monero the railroad passes through a sharp canyon in which the basal sandstone of the Mesaverde forms conspicuous cliffs. The westward dip of the rocks brings the coal beds that overlie this basal sandstone down to the level of the railroad at Monero, where the coal has been mined for many years. The Mesaverde here does not differ notably in character from the Mesaverde of the Durango region, and according to Schrader (100), was traced from Durango to Monero.

A few very poorly preserved leaves were found associated with the Mesaverde coals near Monero. They are *Brachyphyllum* sp., *Myrica* or *Eucalyptus* (n. sp.), and *Ficus* n. sp. The fossil plants seem to be restricted to very narrow zones, and the sandstone both below and above the coal beds contains marine fossils. *Ostrea* sp., *Pecten* sp., *Inoceramus barabini* Morton, and *Baculites anceps* var. *obtusus* Meek (United States Geological Society locality number 7206) were collected near Monero from a sandstone a few feet above the highest bed of coal.

The Lewis shale occupies a broad valley between Monero and Dulce. Its thickness was estimated at 1,000 feet, but this estimate may be too low, inasmuch as the measured thickness both west and south of Monero is 2,000 to 2,500 feet (100, page 242) and (110, page 339). Schrader traced this shale continuously around the northern rim of the San Juan Basin, and thus proved it to be the eastward extension of the typical Lewis shale. About half a mile north of Dulce this shale is very fossiliferous, and the following shells were collected from it at two horizons. They occur in limestone concretions distributed somewhat sparingly

through the upper half of the shale, which is perfectly exposed in a steep barren slope. The first lot (7200) of the following list is from the upper 100 feet, and the second lot (7201) is from a horizon 300 to 500 feet below the top of the shale.

Shells collected from the Shale Slope about half a Mile North of Dulce, New Mexico

United States Geological Survey locality numbers....	(7200)	(7201)
Ostrea pellucida M. & H.?		×
" sp.	×	
Anomia sp.		×
Syncyclonema rigida H. & M.		×
" sp.	×	
Inoceramus sagensis Owen	×	×
" *oblongus* Meek?		×
Modiola sp.	×	
Cardium speciosum M. & H.	×	
Pinna lakesi White?		×
Trigonarca (*Breviarca*) *exigua* M. & H.		×
Lucina occidentalis (Morton)		×
Thetis circularis M. & H.	×	×
Pyrifusus sp.		×
Tellina sp.	×	
Mactra? sp.	×	
Liopistha undata M. & H.	×	
Lunatia sp.	×	
Fusus? sp.	×	×
Anysomyon patelliformis M. & H.		×
Actæon sp.	×	×
Haminea sp.		×
Baculites ovatus Say		×
" *compressus* Say		×
Ancyloceras sp.		×
Scaphites nodosus Owen		×
Placenticeras whitfieldi Hyatt	×	×
" *intercalare* M. & H.		×
Fish scales		×

There is above the Lewis shale a series of rocks not less than 1,000 feet thick, somewhat shaly in the lower part, where a thin bed of coal occurs, but consisting principally of massive sandstone more or less conglomeratic throughout. Apparently some of the older geologists referred this whole series to the Laramie. Others referred some of it to the Laramie and some to the Tertiary. Schrader (100) described the lower or coal-bearing portion as "Laramie," and proved, by tracing the beds, that it is identical with the "Laramie" of the Durango region. The following

fossil plants were found by the present writer a few feet above the coal both north and south of the railroad near Dulce:

Fossil Plants collected from the "Laramie" near Dulce, New Mexico

(United States Geological Survey locality number 6042)

(Those marked (*) occur also in the "Laramie" near Durango, Colorado)

**Brachyphyllum macrocarpum* Newb.
**Sequoia reichenbachi* (Gein.) Heer
Cunninghamites sp.?
**Geinitzia formosa* Heer
Palm (same as species at Point of Rocks)
Ficus planicostata ? Lesq. (same as species at Point of Rocks)
**Ficus* n. sp. (3-nerved)
**Ficus lanceolata* Heer
Zizyphus n. sp.

The flora is essentially the same as that described from the "Laramie" of the Durango section, and confirms the statement that the beds are of the same age. It also strengthens Doctor Knowlton's opinion, previously quoted, that the beds may be older than Laramie, inasmuch as two of the species are found at Point of Rocks, Wyoming, in a formation regarded as older than Laramie, and others are found in the Mesaverde at the localities farther south, described in this paper. In commenting on these plants, Knowlton says: "Their age is essentially Montana and not Laramie. If uninfluenced by their apparent stratigraphic position, I should incline to place them in the Mesaverde, but since they are above Lewis they obviously can not be Mesaverde, though they can be—and in my opinion are—still Montana."

The writer found no invertebrates in the "Laramie" near Dulce, but J. H. Gardner collected some from this formation near Pagosa Junction, about 15 miles northwest of Dulce. They are as follows:

Fossils collected in southeast One-quarter, Section 19, Township 34 North, Range 4 West, near Pagosa Junction, Colorado, 5 feet above Laramie (?) Coal Number 1

Ostrea subtrigonalis E. & S.
Anomia sp. cf. *A. micronema* Meek
Corbicula cytheriformis M. & H.
Corbula undifera Meek

The rocks above the Lewis shale in the Dulce area, referable to the Cretaceous, are only about 225 feet thick, including the basal sandstone, which is 60 feet thick. A section of them and of the rocks underlying them was measured in the steep canyon wall about a mile northwest of Dulce. At this locality a conglomerate that varies greatly in thickness

and character within short distances rests unconformably on the coal-bearing rocks. For about 75 feet above this basal conglomerate the rock is variable in lithologic character and consists of friable, granular sandstone and shale, irregularly intermingled, and in it are many lenses and irregular masses of conglomerate. The whole mass is dark colored and gives the impression of being the erosional product of a mass of dark-colored igneous rock. The suggestion is offered that this formation may represent the Animas formation of the Durango region, although its stratigraphic position would tend to make it somewhat older than the Animas.

Section of Rocks measured about one Mile Northwest of Dulce, New Mexico

	Feet
Sandstone, conglomeratic, brown	80+
Sandstone, slightly shaly, with greenish tint at base; massive, yellow above	44
Shale and sandstone, yellow	121
Sandstone, shaly, greenish	6
Conglomerate with pebbles, principally of chert, up to one-half inch in diameter	12
Sandstone, shaly, gray	27
Conglomerate with chert pebbles up to three-quarters inch in diameter	28
Shale, sandy, yellow	8
Sandstone, white	3
Shale, sandy, yellow	10
Conglomerate with chert pebbles up to three-quarters inch in diameter	38
Shale, sandy, yellow	18
Sandstone, massive, coarse-grained, yellow	66
Shale, sandy, dark-colored	21
Sandstone, friable, dark-colored	46
Sandstone, coarse-grained, conglomeratic, with pebbles mostly of chert up to an inch or more in diameter	6
(Unconformity by erosion.)	
Shale, sandy, carbonaceous; contains fossil leaves (U. S. G. S. locality No. 6042)	83
Coal, coke, and intruded igneous rock	8
Sandstone, coarse-grained, light-colored	66
Shale, sandy	8
Sandstone, massive, light-colored	60
Shale (Lewis), fossiliferous (U. S. G. S. locality Nos. 7200 and 7201)	300+
Total	1,059

The writer found no fossils in rocks above the unconformity, but other geologists seem to have been more fortunate. J. H. Gardner, who is familiar with this region, has, at the writer's request, furnished the following information in a letter dated December 26, 1911:

"I have carried a reconnaissance survey around the north side of the San Juan Basin and have done the details of the Ignacio folio which lies to the west but on the rim of the same basin. There is no doubt in my mind, based on reconnaissance mapping and lithological similarity, that the beds to which you refer (those above the unconformity) are Animas. . . . The heavy conglomerate beds at the base of the Animas are in the form of a lentil which thins out away from the Animas Valley. The beds above this consist of tan-colored and greenish shale alternating with coarse-grained, tan-colored sandstone containing grains of igneous origin. . . . The beds which are intruded with sills along the canyon and cross-cut by dikes (the upper 461 feet of the foregoing section) are of the same nature and apparently connect with the upper beds of the Animas. They are older than the Puerco and Torrejon, and contain remains of Triceratops."

CABEZON

The writer made few observations between Dulce and Cabezon, a distance of about 90 miles. Doctor Gardner (116) correlated the rock formations exposed near Cabezon with those of the Durango region and gave them the same names, namely, Mancos, Mesaverde, Lewis, and "Laramie." The correlation is based on the work of tracing the outcrops of these formations around the San Juan Basin from their type locality in southwest Colorado. They are described as more or less continuously exposed on the west and south sides of the basin, but for a short distance west of Nacimienta Mountains they are covered by overlapping Tertiary rocks. However, in spite of the great length of outcrop around the basin to the west and the area of obscured outcrops on the east side, Doctor Gardner seems to have felt confident that the formations near Cabezon are to be correlated directly with those of the Durango section. He collected fossils from both the Lewis shale and the Mesaverde formations. They are among the United States Geological Survey collections and have been identified by T. W. Stanton. Two collections were obtained from the Lewis as follows:

Invertebrates collected by J. H. Gardner from about 100 Feet below the Top of the Lewis Shale about 6 Miles Southeast of Raton Spring, New Mexico

(United States Geological Survey locality number 4455)

Ostrea sp.
Cardium speciosum M. & H.
Legumen sp.
Liopistha undata M. & H.
Lunatia sp.
Melania? sp.

Invertebrates collected from the Lewis Shale by J. H. Gardner two and one-half Miles Southeast of Cuba, New Mexico

(United States Geological Survey locality number 4452)

Inoceramus barabini Morton
Baculites compressus Say
Placenticeras intercalare M. & H.

His Mesaverde fossils, collected near Cuba, are as follows:

Invertebrates collected near the Base of the Mesaverde Formation, three-quarters of a Mile North of Copper City, New Mexico

(United States Geological Survey locality number 4453)

Nucula sp.
Cucullæa sp.
Arca sp.
Cardium sp.
Cyprimeria? sp.
Liopistha undata M. & H.
Mactra sp.
Gyrodes sp.
Pyrifusus? sp.
Volutoderma sp.
Actæon sp.
Baculites anceps var. *obtusus* Meek
Placenticeras intercalare M. & H.
Placenticeras sp.
Heliococeras sp.
Scaphites sp. related to *S. larvæformis* M. & H.

While in the field the present writer assumed that the Mesaverde age of the coal measures near Cabezon was established, and his purpose in visiting this locality was to collect fossils from the Mesaverde for the purpose of correlating with it the coal-bearing rocks which in the fields farther east contain similar fossils. A large number of petrified logs and stumps of trees were found in the lower part of the Mesaverde north of Cabezon, and leaf impressions occur in the same beds, but most of these were too poorly preserved for identification. However, beautifully preserved leaves were found in a thin layer of fine-grained sandstone about 400 feet above the lowest bed of coal. The locality is about 5 miles northwest of Cabezon, in a steep bluff half a mile north of a small artificial lake. The species collected are as follows:

Fossil Plants collected from the Mesaverde Formation, North 43 Degrees West from Cabezon Butte

(United States Geological Survey locality number 6038)

Ficus speciosissima Ward
Ficus n. sp. (3-nerved)
Dryopteris n. sp. (same species found in lower group of coal beds at Canyon City, Colorado)
Dyospyros sp.
Ficus n. sp.
Myrica sp.
Eucalyptus sp.
Dombeyopsis? sp.
Two or three undescribed dicotyledons

Fragments of palm leaves were found 50 to 100 feet above the bed yielding these plants, but no fragment was found with the parts necessary for the identification of species. Still higher in the formation, at the

east end of Chacra Mesa, several conifers of the species *Abietites dubius* Lesq. were found.

Two small collections of shells were made from the Mancos shale near Cabezon. One was obtained from the sandy layers at the top of the formation in the transitional zone between the Mancos and the basal sandstone of the Mesaverde. They were found at the point where the wagon road leading northwestward from Cabezon crosses the top of the Mancos shale. They are as follows:

Fossils from the Top of the Mancos Shale, Northwest of Cabezon

(United States Geological Survey locality number 7194)

Ostrea elegantula Newberry ?
Anomia sp.
Pinna sp.
Cardium sp.
Cyprimeria sp.
Tellina sp.
Liopistha undata M. & H. ?
Mactra sp., related to *M. formosa* M. & H.
Corbula sp.
Gyrodes sp.
Actæon sp.
Placenticeras sancarlosense Hyatt.

The second collection was obtained from the low hill back of the town of Cabezon at a horizon several hundred feet below the top of the Mancos shale. The rocks containing them are somewhat sandy, and this fact may serve to explain the resemblance of the fauna to that yielded by the sandstones of the Mesaverde. The fossils are as follows:

Fossil Shells collected at Cabezon, New Mexico
(United States Geological Survey locality number 7195)

Exogyra sp.
Anomia sp.
Avicula linguiformis E. & S.
Inoceramus barabini Morton?
Mytilus sp.
Cucullœa sp.
Crassatellites ? sp.
Cyprimeria sp.
Gyrodes sp.
Volutomorpha sp.
Volutoderma ? sp.
Liopeplum sp.
Pyrifusus ? sp.
Placenticeras sancarlosense Hyatt?
Stantonoceras pseudocostatum Johnson?
Lamna sp. (shark's teeth)

From a study of fossils collected from the Mancos, in the vicinity of Cabezon, Shimer and Blodgett (109, page 58) arrived at the conclusion that the shale was of Benton age. They found many Benton species associated with a few which they regarded as belonging to the Pierre fauna. However, the exact horizons of their collections are not known to the present writer, and it is possible that they may be somewhat lower than the horizons at which the fossils named above were found. In the light of the more recent investigations, Doctor Stanton is of the opinion that

these fossils belong to the fauna occurring in the coal measures in the Rio Puerco field, which in turn are referred by him to the lower part of the Montana.

Shimer and Blodgett describe the Mancos shale from several localities between Cabezon and the Rio Puerco field. They report a characteristic Benton fauna from low in the shale corresponding to the Concretion (Septaria) zone of Herrick and Johnson, and a separate fauna from higher in this shale supposed to correspond in general with the Caphalopod zone of Herrick and Johnson. The upper zone of these writers contains a large number of Benton species, together with a few which they regard as characteristic of the Pierre (see 109). Their work serves to connect the formations observed near Cabezon with those of the Rio Puerco field, for although the Mesaverde is not continuous between the two fields the Mancos is continuous and the overlying Mesaverde occurs in Prieta Mesa and probably also at Cabezon Butte, so that there are only three short breaks in its continuity between the large area occupied by this formation in the San Juan Basin and the smaller area in Rio Puerco field.

RIO PUERCO FIELD

Aside from brief references in the accounts of early explorations to the occurrence of coal, the first geologic information of the Rio Puerco coal field was given by Herrick and Johnson (77). The various zones described by them and the fossils contained in each zone are named in the notes of the annotated list of publications (77) in the latter part of this paper. These zones were found convenient for use by the present writer and are here used in a quotational way.

The Cretaceous rocks of this field dip toward the east, the degree of dip varying greatly from place to place, and disappear under a cover of Tertiary and Quaternary rocks in the Rio Grande Valley. A section showing the main features of the Cretaceous rocks below the Mesaverde was measured near San Francisco. The line along which the measurements were made extends across the gently dipping rocks from the Dakota (?) outcrop northwest of San Francisco to Punta de la Mesa farther to the south. The fossils collected from the several horizons are named in the section:

Section of Rocks measured in the Rio Puerco Coal Field near San Francisco, New Mexico

	Feet
Sandstone, massive, yellow (Punta de la Mesa sandstone or base of Mesaverde)	77
Shale, sandy at top	240±
Limestone, shaly, containing *Ostrea lugubris* Conrad and *Coilopoceras colleti* Hyatt (U. S. G. S. locality No. 3515)	10±

	Feet
Shale	50
Shale with limestone concretions (Cephalopod zone) containing *Pinna petrina* White?; *Pecten* sp.; *Trigonarca* sp.; *Isocardia* sp.; *Veniella?* sp.; *Cardium* sp.; *Turritella* sp.; *Volutoderma* sp.; undetermined gastropods; *Metoicoceras* sp. related to *M. swallovi* (Shumard); *Metoicoceras* sp. (U. S. G. S. locality No. 3520)	10±
Shale. In the lower part were found *Ostrea* sp.; *Avicula gastrodes* Meek; *Pinna petrina* White; *Veniella* sp.; *Pholadomya* sp.; *Turritella* sp. related to *T. whitei* Stanton; *Metoicoceras* sp. (U. S. G. S. locality No. 7191). The fossils were collected at some distance from the line of measurement of the section and may possibly belong to the Cephaloped zone	600±
Sandstone, shaly, with impure limestone in lenses and concretions. (This sandstone and the limestone concretions above and below it seem to constitute the Concretion (Septaria) zone of Herrick and Johnson.) It contains *Ostrea* sp.; *Exogyra columbella* Meek; *Anomia* sp.; *Avicula gastrodes* Meek; *Cardium* sp.; *Legumen* sp.; *Pecten* sp.; *Pinna petrina* White; *Isocardia* sp.; *Liopistha* (*Psilomya*) sp.; *Anchura* sp.; *Prionotropis* sp.; *Acanthoceras*? sp. (U. S. G. S. locality Nos. 7192 and 3513)	50×
Shale alternating with layers of yellow sandstone	78
Shale, carbonaceous, dark-colored; has general aspect of the shale associated with the coal beds of the Mesaverde in this field	2
Sandstone, coarse-grained above, shaly below; weathers to irregular, rounded masses; contains *Halymenites* similar to *H. major* Lesq., worm borings, and a variety of indefinite markings	25
Shale, dark-colored (Gastropod zone), containing *Ostrea* sp.; *Exogyra columbella* Meek; *Camptonectes symmetrica* Herrick and Johnson; *Plicatula* sp.; *Gervilliopsis*? sp.; *Pinna petrina* White; *Pinna* sp.; *Liopistha* (*Psilomya*) sp.; *Arca* sp.; *Trigonarca* sp.; *Cardium* sp.; *Lucina* sp.; *Turritella* sp.; *Anchura fusiformis* White non Meek; *Anchura* sp.; *Cinulia*? sp.; *Serpula* sp. (U. S. G. S. locality Nos. 7205, 3517, and 3518)	35
Sandstone, soft, friable; contains small pebbles, principally of quartz and chert	5
Sandstone, yellow	8
(Abrupt change in lithology.)	
Sandstone, coarse-grained, gray to pink; varies greatly from place to place in thickness, composition, and color. This sandstone has the stratigraphic position of the Dakota, but its color and variable character are suggestive of Morrison	100
Sandstone and shale, variegated (Morrison).	
	1,290

Two collections of fossils were made east of the Rio Puerco about 3 miles north of San Francisco. The first is from a zone of limestone concretions that seems to occupy a horizon about 50 feet above the top of the

Tres Hermanos sandstone. The following species were collected at this locality:

Fossil Shells collected East of the Rio Puerco, about 3 Miles North of San Francisco, New Mexico

(United States Geological Survey locality number 7204)

Ostrea sp.
Pinna petrina White
Cardium sp.
Lunatia sp.
Turritella sp.
Prionotropis sp.
Metoicoceras sp.
Coilopoceras colleti Hyatt

The second collection is from an exposure about half a mile east of the first and estimated to be stratigraphically higher by about 100 feet. The strata here dip very slightly to the east and the rocks are covered with soil in most places. The shells collected at the higher horizon are as follows:

Shells collected East of the Rio Puerco, about 3 Miles North of San Francisco, New Mexico

(United States Geological Survey locality number 7193)

Ostrea lugubris Conrad
Anomia sp.
Inoceramus fragilis H. & M.
Anchura sp.
Anisomyon ? sp.
Baculites gracilis Shumard?
Prionocyclus wyomingensis Meek
Scaphites warreni M. & H.
Ptychodus sp. (fish teeth)

These fossils seem to indicate horizons several hundred feet above the base of the Mancos, namely, near the Caphalopod zone, whereas their apparent position as observed in the field is near the base of the Mancos about 500 feet below the Caphalopod zone. It is possible that the rocks have been faulted, so that the position of this zone in the section is deceptive, but no indication of faults with displacement of more than 25 feet was noted near these localities.

More detailed investigation of the Mancos from Rio Puerco westward is necessary before its subdivisions and their relations to each other and to neighboring formations are properly understood. The rocks dip at low angles and broad grassy valleys occur at the outcrops of the shale. The rocks are faulted and warped in some parts of this field, and it is difficult to find a place where there is no liability of error in measuring the shale in these broad valleys. Furthermore, the fauna is not so well known that the vertical range of all the species can be confidently given. A section measured by Darton (114, page 60) near Laguna, at the southwestern extremity of the area shown on the accompanying map, is

given. The fossils seen indicate a position near the base of the Mancos about the horizon of the Tres Hermanos sandstone, and yet they occur above a body of shale much thicker than any reported elsewhere below this sandstone.

Section of Part of Cretaceous Rocks 2 Miles Northeast of Laguna, New Mexico

Measured by N. H. Darton

	Feet
Lava	..
Sandstone	25
Shale	60
Sandstone, buff, massive, moderately soft	40
Shale with sandstone layers, very fossiliferous; contains *Exogyra columbella* Meek; *Gryphæa* sp.; probably a variety of *G. newberryi; Avicula gastrodes* Meek?; *Cardium* sp.; *Panopea* sp.; *Turritella* sp.; *Rostellites volutoderma* sp., and *Fusus* sp.	..
Sandstone, massive, hard, light buff	40
Shale, dark gray to gray-green, sandy layers fossiliferous; contains *Exogyra columbella* Meek; *Pecten* sp.; *Pinna petrina* White; *Inoceramus*? sp.; *Leda* sp.; *Cardium* sp.; *Lucina*? sp.; *Isocardia* n. sp.; *Cyprimeria?* sp.; *Corbula* sp.; *Liopistha* (*Psilomya*) *concentrica* Stanton; *Turritella whitei* Stanton; *Tritonium Kanabense* Stanton; *Actæon* sp.; *Cinulia* sp.; *Turrilites?* sp., or *Heteroceras* sp.	60
Sandstone, hard, red, irony	5
Sandstone, white, massive, part coarse	80
Shale, greenish gray, sandy above	235
Sandstone, hard, buff, massive	40
Shale, soft	30
Sandstone (basal bed of Cretaceous)	..
Total	490

No place was found where a complete detailed section of the Mesaverde formation of the Rio Puerco field could be measured. The beds are well exposed in only a few places, and where they are exposed some of them are warped to such an extent that it is difficult to trace individual beds for any considerable distance, and others are faulted so that certain beds are duplicated; also, some of the upper part of the formation seems to have been removed by erosion previous to the deposition of the overlying Tertiary rocks, inasmuch as the lowest bed observed in the Tertiary is a conglomerate. A generalized section was measured east of the Rio Puerco, about 3 miles north of San Ygnacio, where many fossils were collected. A section of the upper part of the coal-bearing rocks was measured in detail about a mile farther north by L. C. Chapman, who was assisting the writer in doing the field work. This has been incorporated in the general section below. Where the section was measured,

faulting has occurred in a way that renders the relation of the Mesaverde to the Tertiary open to question; but near the northern end of the Rio Puerco field an exposure was found of rocks undisturbed by faulting where the basal conglomerate of the Tertiary with pebbles of quartzite up to 6 inches in diameter rests on the Mesaverde.

Section of Mesaverde Rocks measured near San Ygnacio, New Mexico

	Feet	Inches
Sandstone, locally conglomeratic, and shale (Tertiary) poorly consolidated, vari-colored, with reds predominating below and milder shades above (many hundreds of feet)	..	..
Probable unconformity	..	..
Shale with thin beds of coal; absent in some places	0-10	..
Sandstone, massive, yellow, calcareous, and shaly in some places; contains *Ostrea* sp., *Anomia* sp., *Inoceramus* sp. (thick-shelled); *Cucullæa* sp.; *Cardium* sp. (large form); *Cardium* sp. (slender form); *Tellina* sp.; *Cyprimeria* sp.; *Liopistha undata* M. & H.?; *Corbula* sp.; *Mactra* sp., related to *M. formosa* M. & H.; *Mactra* sp. (large form); *Dentalium* sp.; *Gyrodes* sp.; *Physa* ? sp.; *Volutomorpha novimexicana* Herrick & Johnson; *Pyropsis* sp.; *Actæon* ? sp.; *Scapnites* sp., related to *S. nodosus* Owen; *Placenticeras sancarlosense* Hyatt?; *Placenticeras planum* Hyatt? (U. S. G. S. locality No. 7189)	300±	
Shale, sandy, containing *Brachyphyllum* ? sp.; *Ficus* n. sp. (3-nerved type); *Salix* ? sp.; *Ficus* ? sp. (large leaf) (U. S. G. S. locality No. 6034)	9	..
Shale, carbonaceous	11	..
Coal	1	1
Shale, carbonaceous	7	..
Sandstone	8	..
Shale, carbonaceous	2	6
Coal	..	7
Shale, carbonaceous	3	6
Sandstone	3	..
Coal	..	1
Shale, carbonaceous	7	..
Coal	..	6
Shale, carbonaceous	10	..
Coal	..	2
Shale, carbonaceous	2	6
Sandstone	1	..
Shale	6	..
Coal	..	5
Shale, carbonaceous	3	6
Coal	..	2
Shale, sandy	2	6
Coal	1	..
Shale, sandy	..	6

	Feet	Inches
Shale	2	6
Coal	1	1
Shale, carbonaceous	9	..
Shale	1	6
Coal	..	5
Shale, carbonaceous	5	..
Coal	..	5
Shale, carbonaceous	2	..
Coal	..	3
Shale, carbonaceous	3	..
Sandstone, coarse-grained	2	..
Shale, carbonaceous	3	..
Coal	1	2
Shale, carbonaceous	15	..
Coal	..	5
Shale, carbonaceous	4	..
Coal	1	9
Shale, sandy, carbonaceous	8	..
Shale, sandy	1	..
Shale, carbonaceous	2	6
Sandstone, coarse-grained, gray	3	..
Shale, carbonaceous, chocolate-colored	5	..
Coal	..	2
Shale, carbonaceous, chocolate-colored	1	6
Sandstone, coarse-grained, massive, gray	30	..
Shale, with layers and lenses of yellow sandstone and earthy limestone containing *Halymenites major* Lesq.; *Ostrea congesta* Conrad; *Inoceramus* sp.; *Lithophagus* ? sp.; *Lamna* sp. (U. S. G. S. locality No. 7190)	400±	..
Sandstone, coarse-grained, yellow to gray; contains the following fossil leaves: *Quercus* sp. serrate, new; *Ficus* n. sp. (3-nerved type); *Ficus* sp.; *Dryophyllum falcatum* Ward (Point of Rocks species); *Dalbergia* n. sp. (same as Hagan No. 6030); *Salix stantoni* ? Kn.; *Viburnum* ? *problematicus* Kn. (U. S. G. S. locality No. 6035)	25±	..
Shale, containing one bed of coal 6 feet thick and several thin beds	100±	..
Sandstone with layers of shale and lenses of impure limestone, fossiliferous, but no collections made	172	..
Sandstone, massive, gray, with lenses of impure yellow limestone near the top, containing *Ostrea* sp.; *Inoceramus* sp. (very thick-shelled form); *Cucullæa* sp.; *Cardium* sp.; *Tellina* sp.; *Liopistha undata* M. & H.?; *Mactra* sp. related to *M. formosa* M. and H.; *Mactra* sp., large form; *Volutomorpha novimexicana* Herrick & Johnson; *Baculites* sp.; *Placenticeras planum* Hyatt; *Lamna* sp. (U. S. G. S. locality No. 7188)	110	..
Shale, carbonaceous, chocolate-colored	27	..
Sandstone, yellow, and shale, in alternating layers	235	..

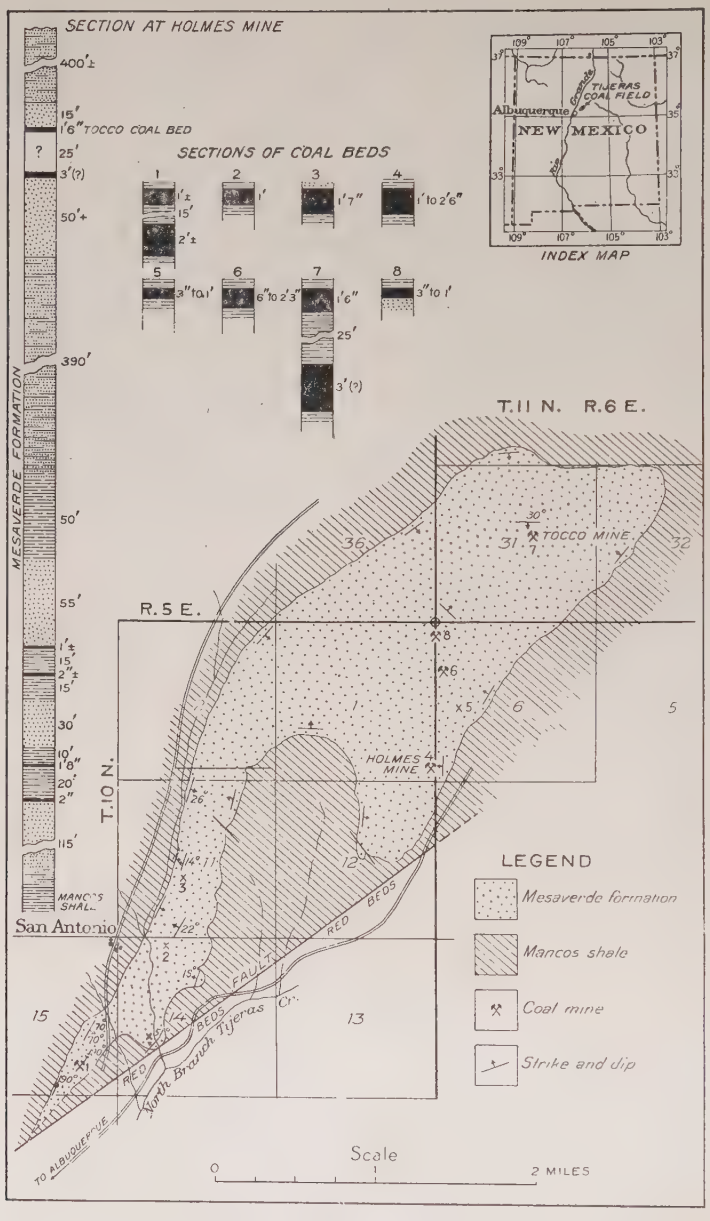

FIGURE 4.—*Map of Tijeras Coal Field, New Mexico*

	Feet	Inches
Shale, yellow to chocolate-colored	57	..
Shale, carbonaceous	5	..
Sandstone, massive, yellow (Punta de la Mesa sandstone), containing *Inoceramus deformis* Meek?; *Avicula* sp.; *Mactra* sp.; *Cardium* sp.; *Anisomyon?* sp.; *Cyprimeria?* sp. (U. S. G. S. locality Nos. 3514 and 3519)	77	..
	1,703	8

TIJERAS COAL FIELD

The Tijeras coal field is located in central New Mexico, about 14 miles south of Hagan and 20 miles east of Albuquerque, on the eastern slope of the Sandia Mountains. The coal-bearing rocks occupy the center of a syncline of irregular outline about 5 miles long and 2 miles wide (see figure 4), lying between the Sandia uplift on the west, the South Mountain uplift on the northeast, and a broad but less well defined uplift on the southeast, which manifests itself within the area mapped by a fault which brings the Carboniferous red beds in contact with the Mancos shale. The coal-bearing rocks are much disturbed by faulting, warping, and crushing, but in general dip from all directions toward the center of the syncline. Along the western margin of the field the strata are upturned to a nearly vertical position. Across the edges of these upturned beds at San Antonio the part of the accompanying section below the coal beds was measured. In the central part of the syncline, although the rocks lie more or less horizontal, they are warped, faulted, and crushed to such an extent that any measurement of their thickness is likely to be deceptive. The part of the accompanying section above the Mancos shale was measured in a canyon at Holmes mine near the center of the syncline, where the rocks seem to be disturbed less than they are in some other places. Nevertheless, the section is given here with some hesitancy because the measured thickness may prove to be quite different from the thicknesses of the beds as originally laid down. The section as measured is as follows:

Section of Rocks measured in the Tijeras Coal Field, New Mexico

		Feet	Inches
Mesaverde or younger	Sandstone, coarse-grained (not continuously exposed, thickness estimated)	400±	..
	Sandstone, gray, coarse-grained, friable; contains fossil leaves *Laurus* ? sp.	15	..
	Coal	1	6
	Not exposed	25	..
	Coal	3±	..
	Not exposed	?	..
	Sandstone, coarse-grained, hard, cliff-making (thickness estimated)	50	..
	(Abrupt change in lithology)		
	Shale and yellow sandstone. The shale predominates in the lower part and the sandstone above; contains *Ostrea* sp.; *Inoceramus barabini* Morton?; *Cucullæa* sp.; *Cyprimeria* sp.; *Legumen* ? sp.; *Gyrodes* sp.; *Volutomorpha novimexicana* Herrick and Johnson ?; *Fusus* ? sp.; *Odontofusus ?* sp. (U. S. G. S. locality No. 7187)	390	..
	Shale, with many thin layers of yellow flaggy sandstone	50	..
Mesaverde	Sandstone, massive; contains *Ostrea* sp.; *Inoceramus* sp.; *Cucullæa* sp.; *Cyprimeria* sp.; *Volutomorpha* sp.; *Pyropsis* sp.; *Placenticeras planum* Hyatt; *Placenticeras sancarlosense* Hyatt; *Baculites* sp.; *Sphenodiscus* ? sp.; *Lama* ? sp. (U. S. G. S. locality No. 7182 and 7185)	55±	..
	Coal with a thin layer of shale containing *Ficus* sp. above it	1±	..
	Shale	15	..
	Coal	2±	..
	Shale, not continuously exposed	15	..
	Sandstone, massive; contains *Ostrea* sp.; *Cucullæa* sp.; *Cucullæa* ? sp.; *Cardium* sp.; *Cyprimeria* sp.; *Mactra* sp.; *Gyrodes* sp.; *Volutomorpha novimexicana* Herrick and Johnson; *Placenticeras sancarlosense* Hyatt (U. S. G. S. locality No. 7184)	30	..
	Shale, with *Myrica torreyi* ? and other plants	10	..
	Coal	1	8
	Shale and sandstone, with thin layers of coal; contains *Cucullæa* sp. and *Cardium* sp.	20	..
	Coal	..	2±
	Sandstone, massive, cliff-making; contains *Cardium* sp.; *Callista* ? sp.; *Volutomorpha* sp. (U. S. G. S. locality No. 7186)	115	..

		Feet	Inches
Mancos	Shale, dark-colored, sandy at the top	1,345	..
	Sandstone (Tres Hermanos), hard, quartzose; contains worm borings and indefinite markings of various kinds	145	..
	Shale, dark-colored, with limestone concretions (Gastropod zone)	60	..
	Sandstone (Dakota)	65	..
	Sandstone and shale, variegated (Morrison)	..	..
		2,812	6

The rocks of the Morrison formation are not well exposed, but where seen near San Antonio do not differ in character from those referred to the Morrison at other localities in central New Mexico. They rest on the gypsiferous red beds of the Manzano group of the Pennsylvanian series (112).

The Dakota sandstone is hard and quartzose, and, together with the Tres Hermanos sandstone, forms a prominent double ridge along the western side of the field where the rocks are upturned to a nearly vertical position. The dark-colored shale of the Gastropod zone is present at this locality, but it is thinner here than it is farther to the north in the Hagan and Cerrillos coal fields. The concretions of limestone found in many places in this shale, and which contain numerous fossils on the Rio Puerco and elsewhere, were observed at San Antonio, but no fossils were collected from them.

A sandstone 145 feet thick occurs above the shale containing the Gastropod zone. No fossils were found in it, but it is stratigraphically and lithologically the same as the Tres Hermanos sandstone of the other fields described in this paper.

The principal mass of the Mancos shale is thinner in the Tijeras field than it is in the Hagan and Cerrillos fields, but this may be due in part to mechanical thinning which may have taken place during the disturbance which upturned the rocks. On the other hand, it may be that the shale originally thinned toward the south as it does toward the west, but the distance of 10 miles between the fields is scarcely enough to render this hypothesis tenable.

There are no fossiliferous lenses of yellow sandstone below the coal beds in the Tijeras field as there are in the Hagan field. It has not been determined whether this absence is to be explained on the assumption that the top of the Mancos shale of the Tijeras field is equivalent to the sandstone lenses of the Hagan field or whether the coal-bearing rocks of the Tijeras field are equivalent in age to the lenses of the Hagan field

and therefore older than the Hagan coals. In many places in the Tijeras field the basal sandstone of the Mesaverde contains marine shells of species identical with those found in the sandstone below the coal in the Hagan field. Coal lies immediately above this sandstone, and associated with it are fossil plants, but only a few poorly preserved specimens were found. The Mesaverde of the Tijeras field is essentially a marine formation and shells were collected from it at several horizons, as indicated in the section.

There is a zone of shale and sandstone above the principal coal beds which contains marine fossils and which may be the equivalent of the Lewis shale of the southern part of the San Juan Basin described by Gardner (116). It is somewhat thicker than the Lewis in the southeastern part of this basin, the locality nearest to the Tijeras field at which the Lewis is known to occur. The fossils named in the accompanying section indicate clearly the marine character of these beds, and if the Tijeras section were compared only with the sections measured in the Hagan and Cerrillos fields to the north it would seem proper to correlate the coal-bearing rocks with the coal measures of the Hagan and Cerrillos sections and refer the marine beds above them to a higher horizon not now represented in the Hagan and Cerrillos fields. On the other hand, if the Tijeras section be compared with that of the Rio Puerco field, it appears that the rocks containing these marine shells may represent one of the marine horizons known to occur within the Mesaverde in that field. The fossil shells seem to favor the latter correlation, for they are not characteristic Lewis species. They do not differ materially from those found at several horizons within the Mesaverde, and because of this fact these rocks are included in the Mesaverde.

These marine beds are overlain by a coarse-grained, hard, cliff-making sandstone, which differs in character and appearance from the sandstone below to such an extent that it suggests the beginning of a new formation. This in turn is overlain by coal-bearing sandstone and shale. If the underlying beds containing the fossils of marine origin prove to be Lewis the higher beds may be regarded as Laramie. No fossils except a few poorly preserved plants were found in them, and these proved to be insufficient for the determination of age. These younger coal-bearing rocks are confined to the trough in the center of the syncline and occupy an area of only a few acres. Coal occurs near the base of the formation, but the rocks intervening between it and the basal sandstone, which is relatively hard, consist of soft sandstone and shale so poorly exposed that the thickness could not be measured. Two coal beds separated by an interval of 25 feet are known to occur in this upper coal-bearing formation.

They were observed at the Tocco coal mine. The rocks above these coal beds consist principally of coarse-grained, friable sandstone, and like the basal sandstone just described are very different in appearance from any of the sandstones associated with the lower coal beds in this field or in the Mesaverde formation of the neighboring fields. For this reason these rocks are regarded as possibly younger than Mesaverde.

HAGAN FIELD

The Hagan coal field lies east of the Rio Grande between the Sandia and the Ortiz Mountains. The Hagan coal mine, from which this field derives its name, is located about 14 miles southwest of Cerrillos. This mine has been described by M. R. Campbell (103, page 429), and the coal beds correlated by him and others with those opened in the same field at the Sloan and the Pina Vititos mines. The rocks of this field dip east at angles varying from 15 to 35 degrees and disappear under accumulations of rock debris of comparatively recent origin. A section of the Cretaceous rocks at Hagan was measured with tapeline across the strike in an east-west direction, and the thicknesses given in the accompanying section were obtained by correcting for dip the distances measured at the outcrop. The rocks lying stratigraphically below the Dakota were described by the writer (112, figure 2, page 19) a few years ago, the top of the section measured at that time coinciding with the base of the following section. The two may be combined to make a complete section of the sedimentary rocks exposed east of the Sandia Mountains.

Section of Rocks measured near Hagan, New Mexico

		Feet	Inches
Recent	Conglomerate consisting of pebbles and boulders up to several feet in diameter (several hundred feet)		
	(Unconformity.)		
Tertiary (?)	Shale and friable sandstone, highly colored in many shades of purple, blue, green, yellow, etc.	2,500	
	Sandstone, conglomeratic, with partings of red shale; a coarse conglomerate occurs at the base. The sandstone is all coarse-grained, granular, and friable	195	
	Shale, sandy in some places, gypsiferous; highly colored like the shale above	750	
	Sandstone, yellow, conglomeratic at the base with pebbles up to 4 inches in diameter in a matrix of loose, friable sandstone. Pebbles consist principally of quartz, quartzite, chert, jasper; sandstone like those of lower horizons and fragments of petrified wood. Sandstone is very		

		Feet	Inches
Tertiary (?)	coarse-grained and more or less friable throughout, and contains great numbers of petrified logs, some of which seem to be of palm wood. Concretions of pink sandstone occur in the lower part	345	
	(Probable unconformity.)		
Mesaverde	Shale, sandy, with soft, friable sandstone. The shale is carbonaceous with thin seams of coal in many places, and several coal beds 1 to 6 inches thick occur near the top. Large concretions of yellow and chocolate-colored, calcareous sandstone, yellow cone-in-cone structure limestone, and ironstone throughout. The following fossil plants were found at the top of this shale half a mile north of Hagan: *Brachyphyllum* sp.; *Ficus* sp.; *Dalbergia* n. sp. (U. S. G. S. locality No. 6030)	600	
	Sandstone in thick, massive plates; forms the crest of the ridge at Hagan mine; fossiliferous.	120	
	Shale, sandy; contains crystals of gypsum and fossiliferous concretions of sandstone. Fossil plants at the top are *Alga; Cyperacites* sp.; *Gleichenia* ? sp.; *Trapa* ? *microphylla* Lesq.; *Nelumbo intermedia* ? Kn.; *Carpites* n. sp. (U. S. G. S. locality No. 6022)	34	
	Coal	1	
	Shale, chocolate-colored	..	6
	Coal	1	
	Sandstone, gray to brown, hard, fine-grained, in layers alternating with shale	12	
	Shale, sandy, gray	3	
	Coal	1	
	Sandstone and shale in alternating layers; contains *Protophyllocladus* sp.; *Ficus lanceolata* Heer; *Ficus* n. sp. (3-nerved); *Quercus* sp. (U. S. G. S. locality No. 6023), 6 to 15 feet	10	
	Sandstone, massive, gray, cross-grained, cross-bedded; contains petrified wood; lies with uneven contact on coal, 5 to 15 feet	10	
	Coal (Hagan mine)	3±	
	Shale, carbonaceous, chocolate-colored	1	
	Sandstone, shaly, and carbonaceous shale	20	
	Sandstone, calcareous, chocolate-colored	4	
	Shale, sandy	25	
	Coal, shaly	1	
	Shale	4	
	Coal	1	6

		Feet	Inches
Mesaverde	Covered. (Thin beds of coal occur at this horizon ½ mile farther north)	82	
	Sandstone, massive, friable, light gray	20	
	Not well exposed. There are several small ridges formed by the outcropping of sandstone layers in which are concretions of chocolate-colored sandstones and fossiliferous limestones; contains *Ostrea elegantula* Newberry; *Ostrea* sp.; *Anomia* sp.; *Syncyclonema* sp.; *Modiola* sp.; *Inoceramus barabini* Morton; *Inoceramus* sp.; *Lithophagus* sp.; *Leda* sp.; *Cucullæa* sp.; *Cardium* sp.; *Legumen* sp. related to *L. planulatum* Conrad; *Liopistha undata* M. and H.; *Tellina* sp.; *Mactra* sp. related to *M. formosa* M. and H.; *Mactra* sp. related to *M. gracilis* M. and H.; *Mactra* sp.; *Turritella* sp.; *Gyrodes* sp.; *Lunatia* sp.; *Pterocerella* sp.; *Fasciolaria* ? sp.; *Turris* sp.; *Pyrifusus* ? sp.; *Pyropsis* ? sp.; *Volutomorpha novimexicana* Herrick and Johnson; *Actæon* sp.; *Placenticeras whitfieldi* Hyatt; *Placenticeras intercalare* M. and H.; *Placenticeras sancarlosense* Hyatt; *Placenticeras planum* Hyatt; *Scaphites* sp. related to *S. hippocrepis* De Kay; *Lamna* sp. (shark's teeth); fish vertebræ (U. S. G. S. localities Nos. 6778 and 7172)	220	
	Shale and sandstone not well exposed	415	
	Sandstone with a subordinate amount of shale. The sandstone occurs in large lenticular masses and contains irregular masses of brownish yellow to chocolate-colored, fossiliferous limestone. Gastropods are most numerous near the base. Contains *Ostrea* sp. related to *O. lugubris* Conrad; *Ostrea* (*Alectryonia*) sp.; *Inoceramus barabini* Morton; *Inoceramus* sp. related to *I. acuteplicatus* Stanton; *Pinna* sp.; *Cucullæa* sp.; *Cardium* sp.; *Crassatellites shumardi* Meek; *Cyprimeria* sp.; *Tellina* sp.; *Turritella* sp.; *Anchura* ? sp.; *Gyrodes* sp.; *Turris* sp.; *Pyrifusus* ? sp.; *Volutomorpha novimexicana* Herrick and Johnson; *Pyropsis* ? sp.; *Odontofusus* ? sp.; *Volutoderma* ? sp.; several undetermined gastropod genera; *Nautilus dekayi* Morton ?; *Placenticeras sancarlosense* Hyatt; *Placenticeras intercalare* M. and H.; *Lamna* sp. (shark's teeth) fish vertebræ (U. S. G. S. localities Nos. 6779 and 7175)	265	

		Feet	Inches
Mancos	Shale with a few layers and concretions of limestone. The upper part, 100 to 200 feet thick, is sandy and yellowish in color, and contains *Anomia* sp.; *Inoceramus* sp. related to *I. acuteplicatus* Stanton; *Inoceramus* sp. related to *I. sagensis* Owen; *Cardium* sp.; *Gyrodes* sp.; *Pyropsis*? sp.; *Volutomorpha novimexicana* Herrick and Johnson (U. S. G. S. locality Nos. 7171 and 7173); but the principal part is dark-colored and contains few fossils, except a very large species of *Inoceramus*. Thin layers of fossiliferous limestone occur near the base and contain *Inoceramus labiatus* Schloth; *Inoceramus fragilis* H. and M.; *Prionocyclus wyomingensis* Meek (U. S. G. S. locality No. 7178)....	1,405	
	Shale with fossiliferous limestone concretions at the top, containing *Ostrea lugubris* Conrad; *Ostrea* sp.; *Inoceramus labiatus* Schloth.; *Inoceramus fragilis* H. and M.; *Pecten* sp.; *Pinna petrina* White; *Cardium* sp.; *Isocardia* sp.; *Anatina* sp.; *Pholadomya* sp.; *Mactra*? sp.; *Turritella* sp. related to *T. whitei* Stanton; *Gyrodes* sp.; *Volutoderma dalli* (Stanton); *Actæon* sp.; *Placenticeras* sp.; *Prionotropis*—two or more species (U. S. G. S. locality No. 7177)	400	
	Limestone containing *Inoceramus labiatus* Schloth	1	
	Shale	175	
	Sandstone (Tres Hermanos), quartzose, consisting of thin, contorted layers with numerous worm borings and markings of many kinds; also poorly preserved gastropods and other shells	5	
	Shale (Gastropod zone)	90	
	Sandstone (Dakota), white, friable, cross-bedded, locally conglomeratic	50	
	Shale (Morrison), variegated, and sandstone....	200	
		7,970	0

The Dakota sandstone is massive, conglomeratic, quartzitic in some places and friable in others, and its thickness changes from 15 to 50 feet or more in relatively short distances. No fossils were found in it, and its reference to the Dakota is based on its similarity in lithologic character and stratigraphic position to the Dakota of neighboring regions.

The Mancos shale here, as elsewhere in the areas described in this paper, includes several more or less well defined members that can be

recognized over wide areas by their lithologic characters and by characteristic fossils. The lowest one, containing the Gastropod zone, so called by Herrick and Johnson (77, page 175), in the Rio Puerco field, is found in a dark-colored shale 90 feet thick, and here, as elsewhere in central New Mexico, contains limestone concretions. However, these are not so fossiliferous as are those of the Gastropod zone on the Rio Puerco. A few imperfect shells, mostly of the genus *Inoceramus,* were seen in it, but none were collected.

The *Tres Hermanos* sandstone (77, page 176) is recognizable in this field, but it is only 5 feet thick where the section was measured. However, it increases to 15 or 20 feet in some places near by. It was observed along the outcrop from a point about 2 miles south of Hagan, northward to Pina Vititos, a distance of about 8 miles, where it disappears under surface debris. It contains a few poorly preserved gastropods and fragments of other shells.

The main body of the Mancos shale overlies the Tres Hermanos sandstone. It was measured and examined with considerable care near Hagan. The lower half of it consists of dark-colored shale containing thin layers and concretions of limestone. The upper half is more or less sandy and weathers to a brownish yellow color. These two subdivisions were readily recognizable throughout the Hagan field. A thin limestone about 175 feet above the base of the shale is full of shells of the species *Inoceramus labiatus,* a characteristic fossil of the Greenhorn limestone. A zone characterized by numerous limestone concretions occurs about 400 feet above this limestone and has been called the Cephalopod zone by Herrick (77, page 177). These concretions are very fossiliferous and yielded the fossils named in the accompanying section (lot number 7177).

In the lower part of this concretion zone a petrified log 10 inches in diameter was found. The interior portions of it are silicified and the silica center is surrounded by an envelope of coal about half an inch thick. Seventy-five feet above the top of the concretion zone the shale contains thin layers of dark-colored limestone containing the fossils named in the accompanying section as lot number 7178. These shells, together with those from the concretion zone below them, belong to the Benton fauna. Several of the species are the same as those that Johnson (81) included in his Benton fauna of the Cerrillos field. The writer visited Johnson's locality near the smelter at Cerrillos and is convinced that the horizon represented there is about the same as that indicated in the accompanying section 75 feet above the Cephalopod zone.

At still higher horizons the Mancos shale contains large Inocerami 18

inches or more in length. The shells are fragile and crumble so easily that none were collected. They appear to be the same species that the writer has observed in many places near the center of the Mancos shale west of the Rocky Mountains and near the middle of the Pierre shale east of these mountains.

The upper part of the Mancos shale formation consists of sandy shale about 700 feet thick which may be the time equivalent of the relatively thin sandy transitional beds at the top of the Mancos in other places. The fossils contained in it (number 7177) do not differ from those of the overlying Mesaverde formation.

The line of separation between the Mancos shale and the Mesaverde formation is here drawn at the base of the massive yellow sandstone above which the coal beds occur. The lower part of this formation is not continuously exposed at Hagan. It consists of sandstones that form prominent ridges and these ridges are separated by depressions in which softer rocks, presumably shale, are poorly exposed. The sandstones are more or less lenticular and no one of them has been traced for any considerable distance. They weather to a rusty yellow color and contain irregular masses of earthy limestone in which great numbers of fossil shells were found. These are named in the accompanying section. They do not differ materially from those found in the shale below. In other words, the rocks here referred, principally on lithologic characters, to the top of the Mancos, and those referred to the base of the Mesaverde are faunally not distinguishable.

The upper part of the coal-bearing rocks of the Mesaverde are well exposed near Hagan mine and contain several beds of coal, two of which have been opened at the mine. Alternating with these beds are layers of carbonaceous shale and chocolate-colored sandstone, in which are fossiliferous concretions of yellow calcareous sandstone similar in general appearance to the concretions at which contain the marine shells at lower horizons. The concretions lying just above the principal opening of the Hagan mine yielded the fossil plants of Mesaverde age (number 6023) named in the section. Leaves and large petrified tree trunks occur at somewhat lower horizons.

The shale between the coal beds contains large crystals of selenite, and this shale, as well as the sandstone associated with it, does not differ in general aspect from the beds of marine origin immediately below the coal. The shaly rocks, about 600 feet thick above the main coal beds, are more variable in constitution than those at lower horizons. The lower part of this shale contains great numbers of concretions of earthy limestone; near the top it is more carbonaceous and in some places contains

several thin beds of coal. These beds have been prospected, but no place was observed where the coal is more than a few inches thick, although a considerable amount of carbonaceous shale was seen.

The measured thickness of 600 feet is probably more than the normal thickness of this shale. The measurement was made across the trough of a tilted syncline and it is possible that the shale has been mechanically thickened. It is not so well exposed and no measurement of its thickness was made farther north, although the interval occupied by it was estimated at considerably less than 600 feet. The rocks at Pina Vititos, which probably represent this shale, were measured as 460 feet thick.

Lying unconformably on these highest coal-bearing rocks is a conglomerate that constitutes the base of an extensive series of rocks younger than the Mesaverde. These rocks are highly colored and consist of shale, sandstone, and conglomerate similar in many ways to the Galisteo sandstone of the Cerrillos coal field, although they differ from the typical Galisteo in being much more shaly; also the conglomerates consist of well rounded pebbles of hard rock, whereas those of the Galisteo sandstone near Cerrillos contain many angular ones and slightly worn blocks of relatively soft rock. However, it should be noted in this connection that the pebbles of the lowest conglomerates near Cerrillos are similar to those in the Hagan field, and that larger and more angular ones are most numerous toward the top of the formation. On the other hand, these colored rocks in the Hagan field are very similar in composition, color, and general appearance to the Tertiary rocks of the Rio Puerco field, 30 miles to the west, and hold the same stratigraphic position. Although it seems probable that these rocks will eventually prove to be the time equivalents of some of the Tertiary formations of the San Juan River region farther west, they are provisionally correlated with the Galisteo sandstone formation. No fossils except petrified wood were found in them. This occurs in the formation at all horizons in the form of tree trunks 1 to 5 feet or more in diameter, and many well worn pebbles of petrified wood, probably derived from tree trunks that were embedded in the eroded portions of the underlying coal measures, were found in the conglomerates.

The youngest rocks near Hagan are coarsely conglomeratic and lie with conspicuous angular unconformity on the eroded edges of the Galisteo (?) red beds northeast of Hagan, on the Mesaverde near Hagan, and on the Mancos shale and the Manzano (Pennsylvanian) red beds farther to the south. They consist principally of blocks of igneous rock derived in recent geologic time mainly from the Ortiz Mountains and constitute part of the formation which in the Cerrillos region was referred by John-

son (83, page 173 et seq.) to the Santa Fe marls and which, according to his definition, included rocks of both Tertiary and Quaternary age. They are the rocks that form the aggraded parts of the high altitude conoplain (90) that has been described from this region.

The Sloan coal mine is located in the Hagan field about 3 miles north of the Hagan mine, and the formations of the Hagan section are all exposed there. The coal beds have been described by M. R. Campbell (103, page 428), who quotes a section of the coal-bearing rocks measured by Charles R. Keyes. The Mancos shale below and the Galisteo (?) formation overlying the Mesaverde are present and are characterized by the same features as those described from Hagan and from Pina Vititos.

The Mesaverde is fossiliferous at several horizons. The massive sandstone underlying the principal coal beds contains *Halymenites major* Lesq. and some of the species of shells that were found in the Mesaverde at Hagan. Fossil leaves, *Ficus speciosissima* Ward, *Ficus* sp. type *F. lanceolata, Ficus* sp. type *F. planecastata,* and several undescribed forms were found in the white sandstone overlying the main bed of coal. These same species were found at about the same horizon in a gulch half a mile south of Sloan mine.

Pina Vititos is the name of a coal mine located at the north end of the Hagan field about 3 miles north of the Sloan mine and about 14 miles west of Cerrillos. All of the formations from Dakota to Tertiary (?) are well exposed in the gulch in which the mine is located. They all dip about 30 degrees east and disappear under a cover of surface debris. Those below the Mesaverde do not differ in kind or character from the Mancos at Hagan and were not examined in detail. A section of the Mesaverde and younger rocks was measured with tapeline in the gulch and the measurements corrected for dip are given in the following section:

Section of Rocks measured at Pina Vititos, New Mexico

		Feet
Recent	Conglomerate and breccia, containing a few pebbles of quartz, chert, etc., but consisting principally of blocks of igneous rock up to 5 feet or more in diameter, cemented to a resistant mass (many hundreds of feet)	..
	Sandstone composed principally of igneous material	165
	Unconformity	..

		Feet
Galisteo (?)	Sandstone, friable, slightly colored	330
	Conglomerate composed principally of colored cherts up to 3 inches in diameter	10
	Sandstone, shaly, friable, variegated in color—shades of pink and yellow predominating	460
	Sandstone, friable, shaly, varicolored, with irregular masses of conglomerate at many horizons consisting principally of pebbles of chert; contains great numbers of petrified logs	1,125
	Sandstone, friable, white to light pink in color; contains pebbles of chert throughout	200
	Sandstone, shaly, dark red	400
	Conglomerate	25
	Sandstone, shaly, locally conglomeratic, pink to white in color	330
	Conglomerate, massive	25
	Sandstone, shaly, locally conglomeratic, pink	525
	Conglomerate, coarse, massive	10
	Sandstone, shaly, friable, varicolored, conglomeratic at many horizons	200
	Sandstone, conglomeratic at the base, more or less shaly above, with conglomerate at many horizons; petrified logs, 1 to 6 feet in diameter are numerous	1,120
	Unconformity	..
Mesaverde	Shale and sandstone with ironstone concretions	460
	Sandstone	10
	Shale with sandstone concretions, 1 foot 6 inches of coal near the top; contains at the base *Ficus* sp. type of *F. lanceolata* Heer; *Ficus* cf. *F. wardii* Kn.; *Ficus* n. sp. (3-nerved); *Viburnum* sp.; undescribed dicotyledons (U. S. G. S. locality No. 6028)	200
	Coal	2±
	Shale	150
	Coal	1
	Shale	3
	Coal	1
	Shale	7
	Coal	1
	Shale	5
	Sandstone, massive, gray	130
	Shale (Mancos), sandy in the upper part, with lenses and concretions of sandstone	..
		5,895+

The Mancos shale is well exposed west of the outcrop of the Mesaverde and does not differ in any essential manner from the Mancos of the Hagan section. As at Hagan, the lower part consists mainly of dark-colored shale and the upper part of sandy shale which weathers to a yel-

lowish brown color and contains fossiliferous concretions of impure limestone. No coal or carbonaceous shale was found below the sandstone that is here regarded as the base of the Mesaverde. The sandy shale is regarded as the transitional zone at the top of the Mancos, although it is quite possible it may be the equivalent in time of the lower part of the Mesaverde of other localities.

At the base of the measured section occurs a massive sandstone that appears to be at the same horizon as that at the base of the Mesaverde at Hagan. Five coal beds exposed in the mine entries, now abandoned, and several prospect openings were observed above this massive sandstone. The coals apparently hold the same position as those previously described from the Sloan and Hagan mines. Fossil plants were found at several horizons closely associated with the coal beds and several were collected principally from the sandstone and shale overlying the main coal bed. They are named as lot number 6028 in the accompanying section.

There is a series of shales and sandstones above the coal-bearing rocks containing ironstone concretions. These rocks may be the time equivalent of the rocks constituting the highest shaly member of the Mesaverde at Hagan. On them, as at Hagan, a conglomerate rests unconformably. It is the basal conglomerate of the colored rocks which are correlated in a general way with the Galisteo sandstone of the Cerrillos field. They contain great numbers of petrified logs, some of them very large. The state of preservation of most of them is poor and no specific determinations have been made. No identifiable fossils have been found in these colored rocks and their geologic age is not definitely known.

The coarse conglomerate which overlies the colored beds is composed principally of igneous material derived from the Ortiz Mountains. It consists of angular blocks of igneous rock varying in diameter from a few inches to several feet. The material is irregularly bedded and the beds dip eastward by about the same degree (30 degrees) as the underlying rocks. The thickness obtained by correcting for dip the distances measured across the strike in the upper part of the gulch, locally known as Devils Canyon, is about 3,000 feet, but this may be in excess of the actual thickness, for the bedding is too irregular to admit of accurate determinations of thickness. It is certain, however, that this conglomerate is many hundreds of feet in thickness. It is the same as the youngest conglomerate of the Hagan section that was described as lying unconformably on the Galisteo (?), Mesaverde, and Mancos formations.

CERRILLOS FIELD

The Cerrillos coal field is better known than those just described, mainly because of the productive mines which have been operated here

for many years. The coal-bearing rocks occupy a syncline between the Ortiz Mountains and Galisteo Creek and extend from the town of Galisteo westward for a distance of about 14 miles. The syncline is unsymmetrical and the rocks are warped and faulted in many places, but in general they dip from all directions toward the center of the syncline. The general geology of this field has been described by D. W. Johnson (83), and no space will be devoted to it in this paper farther than is necessary for an understanding of the age and structural relations of the Cretaceous and younger formations. The coal-bearing rocks are referred to the Mesaverde and are correlated with those of the Hagan, Tijeras, Rio Puerco, and Cabezon coal fields, as indicated in figure 2.

The principal coal beds of the upper part of the Mesaverde formation have been opened at Madrid and their thickness, character, and stratigraphic position are well known from mining operations. Coal has been mined from three beds, the lowest of which, known as the Cook and White coal bed, averages 3 feet in thickness. One hundred feet stratigraphically above this is the Peacock coal bed, averaging 1 foot 8 inches in thickness, and 22 feet higher is the White Ash coal, which normally contains coking bituminous coal, averaging 5 feet 6 inches in thickness. Near Madrid this White Ash coal has been changed to anthracite by the intrusion above the bed of a sheet of igneous rock 400 to 500 feet thick. The anthracite coal averages 3 feet in thickness. From data obtained in mining and kindly furnished to the writer by Mr. G. A. Kaseman, the following section of the coal-bearing rocks at Madrid has been constructed. This section probably furnishes the best standard with which to compare others measured in the Cerrillos coal field, although fossils are so scarce as to be of little assistance in correlating other sections with it.

Section of Rocks exposed at Madrid, New Mexico

	Feet	Inches
Intrusive igneous rock	..	..
Shale, containing fossil plants; *Geinitzia* sp	5±	..
Coal, White Ash bed	5	6
Shale and sandstone	22	..
Coal, Peacock bed	1	8
Shale and sandstone	8	..
Sandstone	20	..
Shale	20	..
Sandstone	20	..
Shale with thin seams of coal	2	..
Shale	6	..
Sandstone	20	..
Shale	3	..
Coal, Cook and White bed	3	..

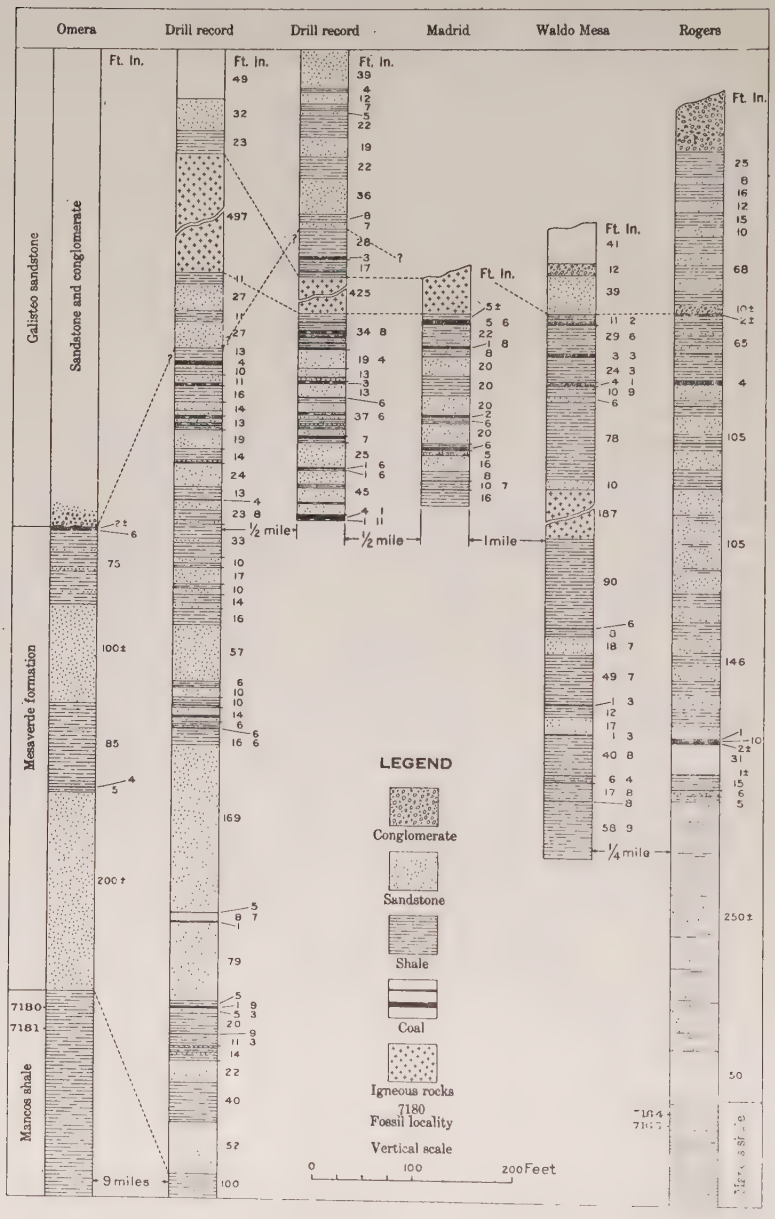

FIGURE 5.—*Geologic Sections and Drill Records in the Cerrillos Coal Field, New Mexico*

	Feet	Inches
Sandstone and shale	5	..
Sandstone	16	..
Shale	8	..
Coal	..	11
Shale	9	..
Coal	..	8
Shale	16	..
	191	9

Few fossils were found in the coal-bearing rocks at Madrid, although careful search was made for them. The shale beds overlying the coal in the mines near Madrid were searched, but at only one locality were fossil plants found in them. This is about a mile south of Madrid in the roof of a prospect opening in the White Ash coal bed, where conifers, identified as probably belonging to the genus *Geinitzia,* were found in shale above the coal. Where the Cook and White bed crosses Coal Gulch north of Madrid this coal bed is overlain by a massive sandstone in which are pinkish brown concretions of sandstone. In one of these concretions were found impressions of shells similar in appearance to some of the shells of marine origin that occur so abundantly in the sandstones at the base of the Mesaverde. The writer found no other shells above the coal beds near Madrid, but J. J. Stevenson (53, page 155) reports the occurrence of *Inoceramus* and *Ostrea* in the coal-bearing rocks.

The rocks at Madrid dip east about 15 degrees, and the mine entries have been driven down this dip under an intrusive sheet of igneous rock which forms the crest of a hill east of the town. Above this sheet and in a gulch about half a mile east of Madrid coal-bearing rocks are exposed near the mouth of an abandoned mine. The following section was measured by D. W. Johnson (83, page 107) at this locality and the section was later confirmed by the present writer. To the fossil plants reported by Doctor Johnson have been added those collected by the writer.

Section of Rocks measured at an abandoned Coal Mine one-half Mile East of Madrid, New Mexico

	Feet
Loose sand, upper part concealed	..
Intruded lava sheet	1
Sandstone, soft	8
Intruded lava sheet	3
Sandstone, soft	10
Sandstone, indurated, containing *Ficus rhamnoides* Kn.; *Ficus uncata* Lesq.; *Ficus speciosissima* ? Ward; *Ficus* sp. type *F. planicostata* Lesq.; *Palmocarpon commune* ? Lesq.; *Geonomites* sp.; *Quercus* ? sp.; *Aralia* ? sp.; (U. S. G. S. locality No. 6019)	9

	Feet
Shale, carbonaceous	10
Sandstone	6
Intruded lava sheet	10
Shale	4
Coal	2
Shale	3
	66+

The rocks of this section lie stratigraphically below the Galisteo sandstone and above the intrusive sheet of igneous rock that overlies the highest or White Ash coal bed at Madrid. The thickness of this intruded rock is shown in the accompanying records of drill-holes. A diamond drill prospect was made in the gulch a few hundred feet northeast of the old mine just mentioned and about 4,500 feet east of the principal opening at the outcrop of the White Ash coal bed. The drill penetrated something like 75 feet of rock that seems to belong to the Galisteo sandstone before it reached the coal-bearing rocks of the Mesaverde, and then encountered beds that seem to be equivalent to those of the section just given. After passing through the igneous rock, a group of coal beds was encountered that doubtless is the same as those opened at Madrid. The record is platted to scale in the third column of figure 5, on page 644.

A second drill-hole was put down 6,800 feet east of the outcrop of the White Ash coal bed. The drill reached a depth of 1,602 feet and penetrated not only the beds represented in the first record, but those of stratigraphic horizons considerably lower. The Galisteo sandstone occupies the surface in this region, but there is nothing in the record to indicate its thickness at this locality except the red or variegated color, which, however, may be caused by the metamorphic action of the intrusive igneous rock. Since no coal is known to occur in the Galisteo sandstone, it seems safe to draw the line of separation between this formation and the Mesaverde above the highest coal bed, as has been done in figure 5. This record shows the occurrence of three groups of coals. The highest group obviously corresponds with that represented by the beds underneath the sheet of intrusive rock in the first record and to those of the Madrid section. The two lower groups probably correspond in stratigraphic position to those described later near Omera farther east and to the lower coals near Rogers west of Madrid. The record is platted to scale in the second column of figure 5.

The dip of the rocks, which is 15 degrees east at Madrid, if unchanged would soon carry a given bed to a considerable depth. However, the dip no doubt lessens eastward toward the center of the basin, and it is

probable that the 1,602-foot hole extends entirely through the Mesaverde formation. The surface in the center is occupied by the Galisteo sandstone and younger rocks, but the underlying Mesaverde reappears from beneath them with opposite dip at the eastern extremity of the basin and was observed near the town of Galisteo, although no details of it were obtained there. However, at the southeastern extremity of the basin one of the Mesaverde coals has been developed at Omera mine. A section of the rocks exposed near this mine was measured. The dip is low, and the thicknesses given in the following section were obtained by pacing across the outcrop and correcting for dip. Hence the section is approximately correct, but it is presented only for the purpose of showing the relation of the Mesaverde formation to the underlying Mancos shale and to the overlying Galisteo sandstone.

Section of Rocks measured at Omera Mine, about 18 Miles Southeast of Cerrillos, New Mexico

		Feet	Inches
	Conglomerates base of Galisteo sandstone. (Unconformity.)		
Mesaverde	Coal (Omera mine)	2±	
	Shale, carbonaceous	0	6
	Shale, with layers of sandstone and cone-in-cone structure limestone (not continuously exposed)	75	..
	Sandstone	100±	..
	Shale, Carbonaceous in some places, with lenses and concretions of sandstone, and cone-in-cone structure limestone. Fossil plants at the base	85	..
	Coal	0	4
	Shale	5	..
	Sandstone, massive, yellow; contains fossil shells	200±	..
	Shale (Mancos) with a sandy transitional zone at the top. Concretions of fossiliferous limestone occur 100 to 150 feet from the top; containing *Exogyra ponderosa* Roemer ?; *Anomia* sp.; *Inoceramus sagensis* Owen ?; *Inoceramus* sp.; *Cucullæa* sp.; *Cyprimeria* sp.; *Volutoderma* ? sp.; *Nautilus* sp.; *Baculites* sp.; *Mortoniceras* sp. related to *M. delawarense* (Morton); *Placenticeras sancarlosense* Hyatt; *Placenticeras* sp.—very large specimens, apparently distinct from either of the foregoing (U. S. G. S. locality No. 7180). A few hundred feet lower in this shale the following fossils occur: *Crassatellites shumardi* Meek ?; *Mactra* sp.; *Gyrodes* sp.; *Volutoderma* ? sp.; *Actæon* ? sp. (U. S. G. S. locality No. 7181)	..	..
		467	10

A comparison of this section with the 1,602-foot drill record seems to show that the lowest bed of coal, which is only 4 inches thick where the section was measured, but which is somewhat thicker in other places, corresponds in stratigraphic position with the lowest coal beds represented in that record; that the 100-foot sandstone of this section finds its counterpart in the 169-foot sandstone of the drill record, and that the coal developed in the Omera mine corresponds in position with the middle group of coal beds of the drill record and with the lowest developed coal of the Rogers section (see figure 5). If this correlation is correct it is evident that a large part of the Mesaverde formation as represented in other parts of the Cerrillos coal field is not present at Omera, and that the unconformity above the Omera coal represents an erosion interval of long duration.

As indicated in the foregoing section, the conglomerate of the Galisteo sandstone rests in some places directly on a coal bed. This bed varies considerably in thickness within short distances. In some places where shale intervenes between the coal and the overlying conglomeratic sandstone the coal bed is 4 to 5 feet thick. In other places where the conglomeratic sandstone rests on it the coal is thinner and in some localities is entirely replaced by the sandstone. This was found to be the case in the mine workings. J. H. Gardner states in his unpublished notes of the Omera mine that 560 feet down an old slope the coal suddenly disappears against a face of sandstone showing no evidence of faulting. He found that this disappearance was due to total erosion of the coal bed previous to the deposition of the sandstone. He also states that at one locality near Omera mine he found two coal beds separated by 9 feet of sandstone, the lower one 3 feet thick and the upper one 4 feet 6 inches thick. At one of the prospect entries, a few rods from the place where the Omera mine section given above was measured, the present writer observed two coal beds as follows:

Section of Rocks measured near Omera Mine

	Feet	Inches
Conglomerate with pebbles of several kinds of rock, including angular fragments of coal	..	..
Coal	0	2
Shale, sandy	2	6
Coal	4	2
Shale	..	..
	6	10

The conglomerate shown at the top of this section constitutes the base of the Galisteo sandstone. In it were found pebbles and boulders up to 6 inches or more in diameter, consisting of quartz, chert, sandstone, limestone, petrified wood, coal, etcetera. This formation is exposed continuously from Omera northward to Galisteo Creek and westward to Madrid.

Below the Mesaverde the Mancos shale occurs in characteristic development. Great numbers of fossils, especially cephalopods, occur in concretions of limestone near the top of the formation. The species collected here are named in the accompanying section. The thickness of the Mancos was estimated to be about the same as that given for it in the Rogers section, but no attempt was made to measure it. It dips gently toward the west and occupies the broad valley on either side of the Santa Fe Central Railroad. At the eastern side of this valley, about 3 miles east of the town of Galisteo, a few Benton fossils were collected. They are *Ostrea* sp., *Inoceramus fragilis* H. & M., *Prionotropis* sp., and undetermined casts of pelecypods and gastropods (United States Geological Survey locality number 7170).

About 2 miles south of the locality where these fossils were collected the Tres Hermanos sandstone was recognized, and between this sandstone and the Dakota the shale which contains the Gastropod zone at the localities described farther west. Below the Mancos shale is a hard conglomeratic sandstone which, on the basis of lithologic character and stratigraphic position, is referred to the Dakota, and under it are variegated sandstone and shale that probably are Morrison.

The rock formations above the Morrison in this eastern limb of the syncline correspond closely with those in the western limb, but below the Morrison there seems to be a difference. East of Omera a massive, cliff-making sandstone, about 100 feet thick, pink to red in color, occurs below the Morrison and lies unconformably on the deep red and purple sandstone and shale of the typical red bed formation of this region. This sandstone has the appearance of the Exeter sandstone (81, page 45) of eastern New Mexico and holds the same stratigraphic position. It was not recognized in the western limb of the syncline in the Cerrillos field, nor farther southwest in the Hagan and Tijeras fields, although it may be represented west of the Rio Puerco by a red cliff-making sandstone which occurs below the Morrison. Below this sandstone east of Omera occur red rocks similar to the Manzano red beds that underlie the Morrison west of the Cerrillos field.

The line of outcrop of the coal beds extends from Omera in a northwesterly direction and seems to pass around the northern base of the

Ortiz Mountains to the coal in the vicinity of Madrid, but in the intervening space the coal is covered with debris from the mountains. North of Omera the coal beds were displaced by the intrusion of the igneous rock of Cerro Pelon, which rests on the basal sandstone of the Mesaverde at its southern end and on Mancos shale farther north. This shale and basal sandstone were observed underlying the Galisteo sandstone north of Cerro Pelon in the vicinity of the town of Galisteo, but no indication was found that any coal occurs there. It seems probable that the erosion which preceded the formation of the Galisteo sandstone removed all rocks that may have existed above the basal sandstone of the Mesaverde in the vicinity of Galisteo. Little was seen of the Mesaverde or of the older rocks between Galisteo and Cerrillos. They are covered for the most part by younger rocks, but near Cerrillos the Mancos and Mesaverde reappear in vertical position upturned by the intrusion of the igneous rocks of the mountains north of this town.

West of Cerrillos the rocks dip steeply to the south and Galisteo Creek flows in a gorge cut along the strike partly in the Mancos shale and partly in the basal sandstone of the Mesaverde formation. About one and one-half miles west of Cerrillos the rocks are well exposed south of the stream, and a section was examined carefully for the purpose of locating the coal beds which have been developed at Rogers, a coal-mining camp west of Madrid, now abandoned. At the horizon where the main coal beds should occur coal was found, but the beds are thin, possibly due to crushing at the time the rocks were upturned. Otherwise the section at this locality does not differ materially from the Rogers section which follows, except that the base of the Galisteo sandstone is more coarsely conglomeratic than it is at Rogers. It consists here of hard quartzose sandstone containing pebbles principally of quartz and chert up to an inch or more in diameter.

Fossil plants were found at this locality at a horizon about 325 feet above the top of the basal sandstone of the Mesaverde. They occur in shale in a railroad cut on the branch line from Waldo to Madrid. They are as follows:

Fossil Leaves collected in a Railroad Cut one and one-half Miles West of Cerrillos

(United States Geological Survey locality number 6021)

Brachyphyllum sp.
Celastrus n. sp.
Ficus speciosissima Ward
Ficus lanccolata Heer
Ficus n. sp. (3-nerved)

South and west of the locality just described on Galisteo Creek the rock formations are well exposed and were traced to Rogers, an abandoned coal camp situated on the western limb of the syncline. The rocks strike nearly north and south and dip 9 degrees east. A section was measured by tapeline from the old Rogers mine westward across the strike of the upturned rocks to a point at the base of the Cretaceous about a mile south of Galisteo Creek. This section may be combined with the Galisteo Canyon section of the Manzano group published by the writer several years ago (110 B, page 18).

Section of Rocks measured near the old Rogers Mine, two Miles southwest of Cerrillos, New Mexico

		Feet	Inches
	Conglomerate (Recent).		
Galisteo	Shale, sandy	25	
	Sandstone, yellow	8	
	Shale, sandy, yellow	16	
	Sandstone, massive	12	
	Shale, sandy, light-colored	15	
	Sandstone, massive, gray	10	
	Shale and sandstone in alternating layers	68	
	Sandstone, massive, coarse-grained, friable, loose-textured to quartzose; locally conglomeratic; variable in thickness and character; contains fossil plants; *Abietites dubius* (?) Lesq.; *Geonomites* sp.; *Dryopteris* ? sp.	10±	
	(Unconformity by erosion.)		
Mesaverde	Coal, thickness irregular, due to erosion; absent in some places	2±	
	Sandstone, shale, and thin beds of coal in alternating layers; contains fossil leaves, conifers and *Nelumbo intermedia* ? Kn.	65	
	Coal (Rogers opening)	4	
	Shale and sandstone; the shale carbonaceous in some places with thin seams of coal	105	
	Sandstone in massive layers separated by thin beds of shale; forms the crest of a ridge	105	
	Sandstone and shale in alternating layers; contains concretions of brown sandstone	146	
	Coal	1	
	Shale (0 to 10 feet)	5	
	Coal	2±	
	Covered	31	
	Coal, dirty	1±	
	Shale, with yellowish limestone concretions, containing *Ostrea* sp. related to *O. soleniscus* Meek	15	
	Coal	0	6
	Sandstone and shale	5	
	Coal	0	6

		Feet	Inches
Mesaverde	Shale	5	
	Sandstone, principally massive, light gray, friable in some places with brown flinty concretions. Thickness varies from place to place, but the lower 50 feet or more forms a prominent cliff—the basal sandstone of the Mesaverde—and contains: *Halymenites major* Lesq.; *Mactra* sp. related to *M. alta* M. and H.; and several gastropods and other shells similar to those found below the basal sandstone	300±	
Mancos	Shale with thin layers of gray sandstone; constitutes the transition zone from the shale below to the base of the Mesaverde; contains *Ostrea elegantula* Newberry?; *Anomia* sp.; *Inoceramus* sp. related to *I. proximus* Tuomey; *Inoceramus* sp. related to *I. barabini* Morton; *Cucullæa* sp.; *Cardium* sp.; *Cyprimeria* sp.; *Legumen*? sp.; *Corbula* sp.; *Mactra*? sp.; *Anatina* sp.; *Dentalium* sp.; *Turritella galisteoensis* Johnson; *Volutomorpha* sp.; *Volutoderma*? sp.; *Nautilus dekayi Morton*?; *Scaphites* sp. related to *S. hippocrepis* De Kay; *Baculites* sp.; *Placenticeras sancarloscnse* Hyatt; *Placenticeras planum* Hyatt (U. S. G. S. localities Nos. 7164 and 7165)	150±	
	Shale, dark-colored, with fossiliferous concretions of limestone near the top and near the bottom	2,100	
	Sandstone (Tres Hermanos), hard, quartzose in thin, irregular layers; weathers yellowish brown; contains shells, numerous worm borings, and indefinite markings of various kinds; also *Halymenites major* Lesq.; *Pinna petrina* White?; *Pecten* sp.; *Gyrodes* sp.; *Turritella* sp. (U. S. G. S. locality No. 7168)	20	
	Shale, dark-colored, with dark brown concretions of impure limestone (Gastropod zone) and a stratum of "crinkly" sandstone one foot thick near the middle	75	
	Conglomerate containing pebbles of quartz and chert up to an inch in diameter	2	
	Shale, carbonaceous, with coal a few inches thick near the top	5	
	Sandstone (Dakota), hard, quartzose, massive, cross-bedded, locally conglomeratic near the base	50±	
	Sandstone, white, more evenly bedded than the hard sandstone overlying it	40±	
	Shale and sandstone, variegated in color	80	
	Conglomerate, cross-bedded, massive; pebbles an inch or more in diameter	10	
	Shale, variegated, and sandstone (Morrison), thickness estimated	200	
		3,689	

The variegated sandstone and shale at the base of the section has been referred to the Morrison on lithologic and stratigraphic grounds. No fossils have been found in it in this region. The lower part, 200 feet or more in thickness, consists of soft shale and friable sandstone of many shades of color. This character has been noted in so many places that it has come to be regarded as more or less diagnostic of the Morrison formation. Above these softer beds is a coarse conglomerate 10 feet thick overlain by 80 feet of variegated sandstone and shale. Were it not for the color of the beds above it this conglomerate might be regarded as the base of the Dakota. However, although conglomerate is rare in the Morrison the reference of the 10-foot conglomerate to this formation seems inevitable; also the overlying thin-bedded sandstone, although white, probably belongs in the Morrison. Between it and the overlying conglomerate, which is here referred to the Dakota, there is an uneven line of separation more or less conspicuous which may mark an unconformity. The writer has formerly shown (112, page 18) that in the Galisteo Canyon the Morrison apparently lies unconformably on the Yeso formation. It seems probable therefore that the Morrison in this region is separated in time from both underlying and overlying formations.

Above the rocks here referred to the Morrison is a sandstone about 50 feet thick, conglomeratic near the base and otherwise similar in character and appearance to the Dakota sandstone throughout the southern Rocky Mountain region. No fossils were found in it, and its reference to the Dakota is based on its lithology and stratigraphic position.

Carbonaceous shale in which coal occurs in some places was found above the Dakota sandstone. The shale and coal are both irregular in thickness and character. The coal was observed in several places and found to vary in thickness from a mere film to about 6 inches. There is a conglomerate above the coal which also varies in thickness and character and is absent in some places. Apparently this carbonaceous shale, coal, and conglomerate belong in the Mancos shale formation and are not to be included in the Dakota. The only place at this locality where a line of separation can rationally be drawn between the Dakota sandstone and the Mancos shale is at the base of the carbonaceous shale, where there is an abrupt change from the shale to the quartzose sandstone below it. On the other hand, there is a tendency on the part of some observers of Rocky Mountain geology to call any coal near this horizon "Dakota coal," and it is probable that although this coal in the Galisteo region clearly lies above the base of the Mancos shale it may be the equivalent in age of some of the so-called Dakota coal of the southern Rocky Mountain region. An attempt was made to find the coal at other localities in the Cerrillos

and Hagan fields, but neither the coal nor the conglomerate overlying it was found. It is evident that both the coal-bearing shale and the conglomerate are local in occurrence and of very restricted distribution.

The shale overlying the conglomerate is ordinary dark-colored clay shale of marine origin. A few shells of the genus Inoceramus were found near the base. A stratum of sandstone and a zone of concretions of impure limestone occur midway of the shale and contain fossils, but none were collected. The limestone concretions probably represent the Gastropod zone of the Rio Puerco field.

The Tres Hermanos sandstone, at this locality only 20 feet thick, overlies the shale containing the Gastropod zone. It is very resistant and forms a hogback more prominent than that of the Dakota. It consists of thin irregular layers of sandstone an inch or less in thickness, on the faces of which are ripple-marks, worm tracks, and markings of many kinds. The sandy layers are separated in some places by films of shale. A few imperfect casts of gastropods were found in this sandstone and impressions supposed to be *Halymenites major* are abundant in some places. The species named in the accompanying section (number 7168) were found in blocks of sandstone at the base of a cliff of the Tres Hermanos sandstone where the section was measured. The sandstone is unlike any other rocks near it and has a peculiar appearance that makes its recognition easy.

At a horizon estimated to be 100 feet stratigraphically above the Tres Hermanos sandstone there is a small ridge formed by a limestone about 3 feet thick which presumably represents the Greenhorn limestone. It contains great numbers of *Inoceramus labiatus* Schloth. At a higher horizon, estimated as 500 feet above the base of the Cretaceous, *Inoceramus labiatus* Schloth. and *Prionocyclus wyomingensis* Meek were found in a limestone having a strong odor of petroleum. These fossils are among those collected by D. W. Johnson at the town of Cerrillos near the smelter and determined by him as belonging to the Colorado fauna (83, page 103). They are as follows:

Fossils collected near the Smelter at Cerrillos, New Mexico

Ostrea lugubris Conrad
Inoceramus labiatus Schlotheim
" *dimidius* White
" *fragilis* H. & M.
" *strongi* Johnson
Scaphites warreni M. & H.
Prionocyclus macombi Meek
" *wyomingensis* Meek
Prionocyclus sp. nov.
Prionotropis woolgari Mantell
Rostellites dalli var. *wellsi* Johnson
" *ambigua* Stanton ?
Acmea cerrillosensis Johnson
Scurria ? *coniformis* Johnson
Beryx sp. undet.

The top of the Mancos shale of this section is particularly rich in fossils. In the upper 200 feet of the shale were found the species named in the section measured near Rogers mine (numbers 7164 and 7165). Another collection reported beyond was made at approximately the same horizon north of Galisteo Creek. In commenting on these fossils Doctor Stanton says: "The horizon is believed to be a short distance above the Austin chalk and the Niobrara limestone—that is, in the lower part of the Montana group."

The base of the Mesaverde formation in the Cerrillos field consists of a massive cliff-making sandstone overlain by other sandstones which are softer and somewhat shaly in places. These sandstones form the surface of a dip slope that is unevenly eroded and their measured thickness is open to question. The measurement of 300 feet, shown in the accompanying section, was obtained by measuring with tapeline across the strike of rocks dipping only 5 to 8 degrees and computing the thickness from the dip and horizontal distance measured. It is not certain that the dip is constant nor that no faults occur. No coal was found in this lower 300 feet of the Mesaverde, but at neighboring localities thin beds of coal occur in rocks that probably are equivalent to these lowest rocks of the formation. The sandstone contains large yellow concretions, consisting of calcareous sandstone, in which marine fossils were found. Some shale occurs, but it seems to be very subordinate in amount. Apparently this 300± feet of sandstone corresponds to the part of the 1,602-foot drill record between the lowest shale and the top of the 169-foot sandstone. This drill record shows the occurrence of the thin beds of coal supposed to occur in the lower part of the Rogers section, but which were not found where the section was measured. The Mesaverde formation at Rogers contains two groups of developed coal beds, the upper one probably equivalent to the group described at Madrid and the lower one to the coals at Omera and to the middle group shown in the 1,602-foot drill record. These relations are best shown in figure 5.

No fossil plants were found in the Mesaverde near Rogers, but oyster shells, identified as *Ostrea* sp. related to *O. soleniscus* Meek, were found about half a mile south of the line along which the section was measured. They occur in yellow concretions similar to those in the basal sandstone of the Mesaverde which yielded Gastropods and other marine fossils indicated in the section. They occur above a thin bed of coal about 50 feet stratigraphically above the lowest coal observed at this locality. The oyster shells are large and no complete ones could be found, but fragments were obtained an inch or more in thickness and 10 inches long.

There is good evidence at Rogers of an unconformity between the Mesa-

verde and the overlying Galisteo sandstone. A coal bed occurs about 65 feet stratigraphically above the coal at the old Rogers opening. This coal is 3 feet or more in thickness in some places and in other places is entirely absent. This variation in thickness is due to irregularities of the upper surface obviously caused by erosion. On this unevenly eroded surface lies a light-colored, coarse-grained sandstone that is locally conglomeratic. No coal nor dark-colored shale, such as is associated with the coal lower in the section, was observed above this sandstone. The rocks above it are pink, blue, green, etcetera, and gradually merge into the undoubted Galisteo sandstone which is typically developed farther to the east.

A few poorly preserved fossil leaves named in the section were found in this basal member of the Galisteo at Rogers, but they are not of a character to render possible the determination of the age of the rocks containing them.

A diamond drill prospect was made on Waldo Mesa about half a mile south of the old Rogers mine. It has been platted to scale in figure 5, on page 644. The drill passed through a group of coal beds that is obviously the same as the upper group of the Rogers section and then penetrated 187 feet of igneous rock. This rock is a part of a great intrusive sheet that is very prominent farther south, but which does not extend northward to the Rogers mine. Apparently it is not the intrusive sheet of the two drill records previously given, but one intruded at a lower horizon. It underlies the coal beds at Madrid, as is well shown in figure 5 of Doctor Johnson's paper (83, page 37).

A second group of coal beds was penetrated by the drill below the sheet of igneous rock, and these seem to be the same as the lower group of developed coals of the Rogers section and the middle group of the 1,602-foot drill record. This correlation of the groups of coal beds at the several localities described seems relatively simple, but it is not so easy to correlate the individual beds. The upper group of the Waldo Mesa drill record corresponds in a general way with the group of coals developed at Madrid, but for some unknown reason there are fewer coal beds than at Madrid. It is possible, on the one hand, that the Waldo Mesa coal beds represent those near the horizon of the Cook and White coal of the Madrid section, and that the higher beds were eroded away previous to the deposition of the Galisteo sandstone at the Waldo mesa locality. On the other hand, it seems probable that the Waldo mesa coals may correspond in position with the higher ones of the Madrid section, and that the lower beds of Waldo mesa may have been destroyed by the intrusion of the igneous rock.

The rock formations near the base of the Cretaceous are well exposed in Canyon del Yeso, about 2 miles north of Galisteo Creek, where the following section of them was measured. Fossils were collected from these formations and included in the descriptive section. That part of the Mancos shale lying stratigraphically above this section was found to be fossiliferous in many places, but it does not lend itself readily to measurement.

Section of Rocks measured in Canyon del Yeso about 2 Miles North of Galisteo Creek.

	Feet
Limestone and shale in alternating layers, containing *Inoceramus labiatus* Schloth. (horizon of Greenhorn limestone)	15
Shale, containing *Prionotropis* sp.	100±
Sandstone (Tres Hermanos), hard, quartzose, with sparkling sand grains, brown to yellow, in thin irregular layers with numerous worm borings and various indefinite markings. In the lower 10 feet the layers of sandstone are separated by thin layers of shale	25
Sandstone, containing *Inoceramus* sp. and *Pinna* sp.	10
Shale (Gastropod zone), dark-colored, with concretions of earthy limestone 20 feet from the top. Some of the concretions are fossiliferous and weather to a rusty yellow powder around the fossils, rendering specific identification difficult. From these concretions were obtained *Ostrea* sp.; *Exogyra columbella* Meek; *Plicatula* sp.; *Lima* sp.; *Pinna* sp.; *Anchura* sp. (U. S. G. S. locality No. 3536)	70
Sandstone (Dakota), conglomeratic at the base	40
Shale, sandy, near the top	10
Sandstone, coarse-grained, cross-bedded, white	70
Sandstone and shale, variegated (Morrison)	

An effort was made to recognize in this section the several zones described from the lower part of the Rogers section located 3 miles farther south. The sandstone and shale, here referred to the Morrison, is similar lithologically to the variegated beds below the 10-foot conglomerate in the Morrison of the Rogers section. The 40-foot conglomerate sandstone is referred to the Dakota and the lower sandstone, 70 feet thick, is probably also Dakota, although it may be equivalent to the beds of the Rogers section lying below the conglomeratic Dakota and there referred with some doubt to the Morrison because it differed lithologically from the overlying Dakota. The rocks above the Dakota in Canyon del Yeso are the same as those similarly situated in the Rogers section. The 70-foot shale corresponds in position to the shale containing the Gastropod zone and the 35 feet of sandstone above it to the Tres Hermanos sandstone of the Rio Puerco field. The Greenhorn limestone horizon was recognized by its characteristic fossil, *Inoceramus labiatus*. Two hundred feet or

more stratigraphically higher in the section there is a zone about 50 feet thick containing large concretions of limestone, many of which are fossiliferous. These concretions contain *Inoceramus fragilis* H. and M., *Volutoderma* sp., *Prionotropis* sp., and *Pachydiscus* n. sp.

Some of the ammonites are very large. *Pachydiscus,* the largest one found, probably measured between 2 and 3 feet across when complete, but only a small part of it was obtained. About 100 feet stratigraphically above the concretions just mentioned some thin layers of limestone in the shale yielded *Ostrea* sp., *Inoceramus fragilis* H. and M., *Inoceramus* sp. related to *I. dimidius* White, *Scaphites warreni* M. and H., and *Prionotropis* sp. (United States Geological Survey locality number 3542).

East of the last named locality the surface is nearly level and the shale is more or less covered with soil. However, in a small ridge about 1,800 feet east of this locality and at a horizon somewhat higher a few poorly preserved specimens of *Inoceramus* were found, which are either *Inoceramus deformis* Meek or a variety closely resembling it. The fossils suggest correlation with the Niobrara formation and also with the Punta de la Mesa sandstone, but the lithology does not admit of either correlation. About a mile farther east and at a still higher horizon the shale contains numerous concretions of limestone which are very fossiliferous. This probably represents the zone of concretions near the top of the Mancos shale west of Rogers that yielded the fossils named in the Rogers section (numbers 7164 and 7165). The following species were collected from these concretions:

Fossils collected about 5 Miles Northwest of Cerrillos, New Mexico

(United States Geological Survey localities numbers 3532 and 7166)

Ostrea sp.
Exogyra ponderosa Roemer
Inoceramus sagensis Owen
" *irregularis* Johnson
" sp.
Leda sp.
Cucullæa ? sp.
Nucula sp.
Cardium sp.
Astarte sp.
Crassatellites shumardi Meek
Cyprimeria sp.
Liopistha undata M. & H.
Corbula sp.
Mactra ? sp.
Gyrodes sp.
Anchura sp.
Nautilus dekayi Morton
Baculites asper Morton?
Hamites sp.
Placenticeras planum Hyatt
" *sancarlosense* Hyatt
Placenticeras sp.
Stantonoceras pseudocostatus Johnson

In commenting on the age relations of these fossils, Stanton states that they are about the same as those from the top of the Mancos in the Rogers section, of which he says:

"The fauna is related to the Gulf and Atlantic Coast Cretaceous faunas more closely than to those of the Rocky Mountain region. Its horizon is believed to be a short distance above that of the Austin chalk and the Niobrara limestone—that is, in the lower part of the Montana group."

This locality is near the place at which Johnson (83, page 105) collected the fossils described by him as Pierre, but inasmuch as no sandstone was found by the writer at this locality it is probable that the fossils are slightly lower than Johnson's in the section. His description is as follows:

"Two miles southwest of Santa Rosa Mountain, where the main wagon road leaves the basalt-capped mesa for the valley below, there are exposed in the valley at the foot of the mesa fossiliferous shales and sandstones. The exposure is not large, but a small arroyo has removed some of the looser shales, leaving still in place the calcareous nodules in which the fossils are most abundant.

"The following species were collected at this locality:

Ostrea congesta Conrad ?
Protocardia rara E. & S. ?
Astarte evansi H. & M.
Nucula subplana M. & H.
Solen cuneatus Gabb. ?
Lingula subspatulata H. & M.
Tritorium kanabense Stanton
Natica sp. undet."
Baculites anceps Lamarck
Hcliococeras pariense White ?
Beryx sp. undet.
Arca madridensis Johnson ?
Cyprimoria ? *sulcata* Johnson
Turritella galisteoensis Johnson
Admetopsis ? *elevata* Johnson

Bibliography and Notes

The following list contains the principal publications in which information is to be found relative to the rock formations of the several coal fields described in this paper, and includes some outside publications which have had a direct influence on investigations in these fields. The publications are arranged in chronological order and brief notes are attached, calling attention to the character of the information relating to the formations here described. These notes are intended to serve the double purpose of pointing out the data presented in each paper and of placing them in such a way that they will form a history of investigation. Since this paper is not primarily concerned with the economic resources of the coal fields, little attention is given to purely economic reports such as mineral resources. However, considerable geologic information is given in some of the economic papers and many of them are included in the list. There are many papers that make only casual reference to the New Mexico coal fields without giving any definite information. Most of these have been omitted. In order that the papers may be

found readily, the form of reference used in the bibliographies of the United States Geological Survey has been followed.

No. Date.

1. 1848. ABERT, J. W.: Report on examination of New Mexico in the years 1846-1847.

   Report Sec. War, 30th Cong., 1st sess., Senate Doc. No. 23, pp. 3-130, 24 plates, map (Washington, 1848); 30th Cong., 1st sess., Ex. Doc. No. 41, pp. 417-546. Washington, 1848.

   (P. 37) Coal was found in the Cerrillos field and on the Rio Puerco. (P. 547) From the Rio Puerco coal beds (at Poblozon) he collected fossils which Bailey determined as Cretaceous.

2. 1848. BAILEY, J. W.: Notes concerning the minerals and fossils collected by Lieut. J. W. Abert while engaged in the geographical examination of New Mexico.

   Report Sec. War, 30th Cong., 1st sess., Senate Ex. Doc. No. 23, pp. 131-132, 3 plates (Washington, 1848); 30th Cong., 1st sess., Ex. Doc. No. 41, pp. 547-548. Washington, 1848.

   Reviewed, Am. Jour. Sci., 2d series, vol. 6, pp. 389-392. 1848.

   The Cretaceous fossils collected by Abert at Poblozon, in the Rio Puerco coal field, New Mexico, are described. (Poblozon is a few miles north of San Ygnacio.)

3. 1848. WISLIZENUS, A.: Memoir of a tour to northern Mexico, connected with Doniphan's expedition in 1846 and 1847, 141 pages, 3 maps. Washington, 1848.

   Geographisches Jahrbuch von Dr. Berghaus (Gotha). 1850.

   Abstract, Am. Jour. Sci., 2d series, vol. 6, pp. 376-386. 1848.

   For the occurrence of coal in the Rio Puerco coal field see accompanying map.

4. 1850. SIMPSON, JAMES H.: Journal of a military reconnaissance from Santa Fe, New Mexico, to the Navajo country.

   Reports of the Secretary of War, with reconnaissance of routes from San Antonio to El Paso, by Johnson and others (etc.), 31st Cong., 1st sess., Senate Ex. Doc. No. 64, pp. 146-148. Washington, 1850.

   (Pp. 72 and 146-147) Coal was found in 1849 on the Rio Puerco north of Cabezon and at several localities farther west in northwestern New Mexico.

5. 1853. HITCHCOCK, EDWARD: Notes on the specimens of rocks and minerals collected.

   Exploration of the Red River of Louisiana in 1852, by Marcy, pp. 163-178. Washington, 1853. 32d Cong., 2d sess., Senate Doc. No. 54.

   (Another edition, pp. 140-155. Washington, 1854.)

   (P. 165) The paper contains a review of the occurrences of coal previously described.

6. 1855. MARCOU, JULES: Résumé of a geological reconnaissance, extending from Napoleon, at the junction of the Arkansas with the Mississippi, to the Pueblo de Los Angeles in California.

No. Date.

Report of exploration for railway route to the Pacific Ocean, near 35th parallel, by Whipple, vol. IV, pp. 40-48, 8° (Washington, 1855), House Doc. 129.

(Also) Explorations for a railway route from the Mississippi to the Pacific, vol. III, part IV, route near the 35th parallel, explored by Whipple. Report of the geology of the route, by Blake, pp. 165-175, plate, 4° (33d Cong., 2d sess., House Ex. Doc. No. 91; also Senate Ex. Doc. No. 78. Washington, 1856).

(P. 45) The Cretaceous coal beds near Tijeras (Tigeras of Marcou) seem to be confused with Carboniferous coal beds which occur in the Sandia Mountains near by. (P. 46) The Cretaceous rocks underlying the coal beds near Galisteo are described.

7. 1856. Blake, William P.: Report on the geology of the route.

Explorations for a railroad route from the Mississippi to the Pacific, vol. 3, part IV; route near the 35th parallel explored by Whipple, 116 pages, maps, plates, 4°, 33d Cong., 2d sess., House Ex. Doc. No. 91. Washington, 1856. Includes report on fossils by J. Hall, pp. 99-105, plates.

(P. 34) The Cretaceous age of the rocks examined by Abert at Poblozon on the Rio Puerco is accepted and Whipple and Marcou are quoted as reporting coal on the Rio Puerco and near Laguna and Cebolleta (p. 36) in rocks which are regarded as Cretaceous.

8. 1860. Blake, William P.: Observations on the geology of the Rocky Mountain chain in the vicinity of Santa Fe, New Mexico (abstract).

Am. Assoc., Proc., vol. 13, pp. 314-319. 1860.

(P. 315) The anthracite coal found in 1857 near Cerrillos is described.

9. 1861. Blake, William P.: Observations on the mineral resources of the Rocky Mountain chain near Santa Fe, and the probable extent southward of the Rocky Mountain gold field.

Boston Soc. Nat. Hist., Proc., vol. 7, pp. 64-70. 1861.

The occurrence of anthracite coal near Cerrillos examined in 1857 is described. In the same connection the author refers to the Carboniferous coal beds at Santa Fe.

10. 1861. Newberry, John S.: Geological report.

Report on the Colorado River of the West, explored in 1857 and 1858 by Lieut. Joseph C. Ives, part III, 154 pages, 6 plates, 4° (36th Cong., 1st sess., Senate Ex. Doc. —). Washington, 1861.

Abstract, Am. Jour. Sci., 2d series, vol. 33, pp. 394-403. 1861.

Some of the coal near Moqui is described as Jurassic (p. 85) and some as Cretaceous, the latter associated with fossil plants similar to those of the Dakota of Kansas and Nebraska. The Cretaceous coal of this author occurs also both east and west of Fort Defiance (in the San Juan coal basin). (P. 100) Carboniferous fossils were obtained from the coal measures at Santa

No. Date.

Fe and samples of the anthracite from near Cerrillos were obtained, but that locality was not visited.

11. 1865. Owen, R. E., and Cox, E. T.: Report on the mines of New Mexico, 60 pages. Washington, 1865.

Abstract, Am. Jour. Sci., 2d series, vol. 40, pp. 391-392 (⅓ p.). 1865.

Anthracite coal, regarded as Carboniferous, is reported at Placer Mountain (Cerrillos field) (pp. 23 and 40), and bituminous coal is reported on the Rio Puerco (p. 24).

12. 1868. Hayden, F. V.: Rocky Mountain coal beds.

Am. Jour. Sci., 2d series, vol. 45, pp. 101-102. 1868.

(P. 102) The author refers briefly to the coal beds in New Mexico and includes them with his Tertiary lignites.

13. 1868. Le Conte, John L.: Notes on the geology of the survey for the extension of the Union Pacific Railway from the Smoky Hill River, Kansas, to the Rio Grande, 76 pages, 8°. Philadelphia, 1868.

(P. 34) Coal is reported near Tijeras, New Mexico; at Tierra Amarilla, about 120 miles northwest of Santa Fe (p. 36); in Rio Puerco Valley (p. 41); and (pp. 38-40) the anthracite near Cerrillos is described and also the occurrence of fossil leaves in the rocks associated with it. The coal is referred to the Cretaceous and said to be older than the Laramie of the Denver Basin ("Marshall formation").

14. 1868. Le Conte, John L.: Cretaceous coals in New Mexico.

Am. Jour. Sci., 2d ser., vol. 45, p. 136 (½ p.). 1868.

The coal beds near Cerrillos are referred to and correlated with coal beds described by Newberry in the lower part of the Cretaceous of northwestern New Mexico.

15. 1869. Hayden, F. V.: Preliminary report for 1869 (see 3d Annual Report, 1873).

16. 1870. Raymond, Rossiter W.: Statistics of mines and mining.

Report, 41st Cong., 2d sess., H. R. Ex. Doc. No. 207, pp. 1-805. Washington, 1870.

The coal beds at "Old Placer Mountain;" also on the Rio Puerco, near Fort Wingate, and elsewhere are described (p. 417).

17. 1871. Newberry, John S. On the age of some western lignites.

New York Lyceum Nat. Hist., Proc., vol. 1, p. 252 (½ p.). 1871.

The coal beds near Cerrillos are referred to the Cretaceous.

18. 1872. Lesquereux, Leo: An enumeration, with descriptions, of some Tertiary fossil plants from specimens procured in the explorations of Dr. F. V. Hayden in 1870.

United States geological survey of Montana and portions of adjacent Territories, preliminary report, F. V. Hayden in charge, 5th Report of progress (Supplement), pp. 1-22. 1872.

No. Date.

Fossil leaves collected from the coal measures near Cerrillos are included among the "Tertiary plants:" *Populus balsomoides* Göpp.; *Quercus platanea* (?) Heer; *Ficus tiliæfolia* Heer; *Platanus guillelmæ* Heer; *Cinnamomum mississippiense* Lesq.; *Magnolia; Carpolithes spirales* Lesq.; *Carpolithes compositus* Lesq.; *Carpolithes mexicanus* Lesq. [Inasmuch as the coal-bearing rocks now known to be Mesaverde were not distinguished by Lesquereux from the younger rocks of probable Tertiary age, and inasmuch as both formations are plant-bearing, it is possible that these fossils may have come from the Tertiary as their names suggest, rather than from the coal-measures, as he supposed.]

19. 1873. HAYDEN, F. V.: Geological report. Report of the United States geological survey of Colorado and New Mexico, Washington, 1869, under F. V. Hayden, 3d Annual Report, pp. 103-199. Washington, 1873.

Abstracts, Am. Nat., vol. 4, pp. 119-121, 1871; Am. Jour. Sci., 2d series, vol. 49, pp. 258-263, 1869.

(The 3d Annual Report was published as a preliminary field report in 1869.)

The coal beds near Cerrillos are described (p. 167). The coal-bearing rocks containing "abundant impressions of deciduous leaves" are referred to the Tertiary, and the Galisteo sandstone is correlated with the Monument Creek formation of the Denver region. The Galisteo is described as lying conformably on the coal measures. (P. 98) An analysis is given of the "Placer" anthracite.

20. 1873. CLARK, R. NEILSON: The Tertiary coal beds of Canyon City, Colorado.

Am. Inst. Mining Eng., Trans., vol. 1, pp. 293-296, plate. 1873.

The occurrence of coal near Cerrillos, New Mexico, is referred to, and E. T. Cox (p. 298) mentions his former visit to the anthracite mine.

21. 1873. LESQUEREUX, LEO: Lignitic formations and fossil flora.

United States geological and geographical survey of the Territories embracing portions of Montana, Idaho, Wyoming, and Utah, F. V. Hayden in charge, 6th Annual Report (for 1872), pp. 317-427. Washington, 1873.

Abstracts, Am. Jour. Sci., 3d series, vol. 6, pp. 441-450; Am. Nat., vol. 8, pp. 217-218 (1/5 p.). 1874.

(P. 363) The author refers to coal measures in Tijeras Canyon, and near San Felipe (probably in the Tijeras and Hagan coal fields); also at other localities farther west. The Placer Mountain coal beds (Cerrillos field) are correlated with those at Raton, New Mexico, and with those of the Canyon City field in Colorado.

22. 1874. COPE, EDWARD D.: On the mutual relations of the Cretaceous and Tertiary formations.

No. Date.

United States geological and geographical survey of the Territories, embracing Colorado, F. V. Hayden in charge (7th) annual report (for 1873),. pp. 427-444, plates. Washington, 1874.

The literature of "The Fort Union or Lignitic Group" is reviewed. In this group are included (p. 432) the Placer Mountain (Cerrillos) coal beds, which are referred to the Cretaceous "near No. 5" (Fox Hills).

23. 1874. Cope, Edward D.: (On the Cretaceous age of the lignite of the West.)

Philadelphia Acad. Sci., Proc., vol. 26, pp. 10-11, 12-13. 1874. Remarks by Le Conte and Frazer, p. 11.

The author finds evidence of Cretaceous age in the "lignitic beds" of northern Colorado and Le Conte states that coal beds in New Mexico are also Cretaceous.

24. 1874. Cope, Edward D.: Review of the Vertebrata of the Cretaceous period found west of the Mississippi River.

United States geological and geographical survey of the Territories, F. V. Hayden in charge, Bull. (vol. 1, 1st series) No. 2, pp. 5-48. Washington, 1874.

Hayden's reference of the "Placer Mountain" coal beds to the base of his Tertiary lignitic group is quoted and the statement is made that "they are nearer to No. 5 (Fox Hills)."

25. 1874. Cope, E. D. Report on the vertebrate paleontology of Colorado.

United States geological and geographical survey, F. V. Hayden in charge, (7th) annual report (for 1873), pp. 444-533, plates. Washington, 1874.

26. 1874. Cope, Edward D.: Notes on the Eocene and Pliocene lacustrine formations of New Mexico, including descriptions of certain new species of Vertebrata.

Geographic explorations and surveys west of the 100th meridian, by Wheeler, annual report, U. S. Army, Chief of Engineers, Annual Report for 1874, Appendix FF, pp. 115-130, Washington, 1874. (This is not Appendix FF of the Engineer's report, vol. II, 1875.)

Abstract, Am. Jour. Sci., 3d series, vol. 9, p. 151 (⅓ p.). 1875.

(P. 116) The Eocene in the vicinity of the Chama River is described as resting unconformably on coal-bearing rocks which occur below fossiliferous marine rocks of Cretaceous age.

27. 1874. Hayden, F. V.: (General report.)

United States geological survey of the Territories, embracing Colorado, F. V. Hayden in charge, (7th) Annual Report for 1873, pp. 17-82. Washington, 1874.

Abstract, Am. Nat., vol. 9, pp. 173-177. 1875.

(P. 27) The coal beds of western New Mexico are included with others of Cretaceous age.

28. 1874. Hayden, F. V.: Remarks on age of lignitic group.

United States geological and geographical survey of the Ter-

No. Date.

ritories, F. V. Hayden in charge, Bull. (vol. 1, 1st series) No. 2, pp. 1-2. Washington, 1874.

The authors refer to the coal beds in western Colorado, western New Mexico, and elsewhere as "of undoubted Cretaceous age."

29. 1874. LESQUEREUX, LEO: On the age of the lignitic formations of the Rocky Mountains.

Am. Jour. Sci., 3d series, vol. 7, pp. 546-557. 1874.

The author discusses the age of the coal beds of New Mexico and repeats his previous reference of them to the Tertiary.

30. 1874. LOEW, OSCAR: A new fossil resin—"Wheelerite."

Am. Jour. Sci., 3d ser., vol. 7, pp. 571-572. 1874.

Resin was found in "Cretaceous lignite beds" near Nacimiento.

31. 1874. NEWBERRY, JOHN S.: On circles of deposition in secondary sedimentary rock, American and foreign.

New York Lyceum Nat. Hist., Proc., 2d series, pp. 122-124. 1874.

Discussed by Wurtz and Day, ibid., pp. 124, 125. 1874.

Brief reference is made to the Cretaceous rocks of New Mexico.

32. 1874. NEWBERRY, JOHN S.: (On the lignite flora of the far west.)

New York Lyceum Nat. Hist., Proc., 2d series, pp. 78-79. 1874.

The author discusses the geologic age of the coal beds of northwestern New Mexico and states that marine fossils occur in rocks above the coal.

33. 1874. NEWBERRY, JOHN S.: On the lignites and plant beds of western America.

Am. Jour. Sci., 3d series, vol. 7, pp. 399-404. 1874.

The geologic age of the coal beds of New Mexico is discussed.

34. 1874. RAYMOND, ROSSITER W.: Remarks on the occurrence of anthracite in New Mexico.

Am. Inst. Mining Eng., Trans., vol. 2, pp. 140-142. 1874.

The author discusses the age of coal beds near Cerrillos and the chemical character of the coal.

35. 1874. STEVENSON, JOHN J.: (Age of Western lignite.)

New York Lyceum Nat. Hist., Proc., vol. 2, pp. 93-94. 1874.

Brief reference is made to the Cretaceous coal beds of western Colorado and northwestern New Mexico.

36. 1875. COPE, EDWARD D.: Report on the geology of that part of northwestern New Mexico examined during the field season of 1874.

Geographical explorations and surveys west of the 100th meridian, by Wheeler, annual report. Annual Report of the Chief of Engineers, U. S. Army, for 1875, part II. Appendix LL, pp. 981-1017, plates. Washington, 1875.

(Appendix LL is published in separate form, pp. 1-196. 1875.)

(Pp. 996-997) Cretaceous beds, Nos. 3 and 4, are described east of Sandia Mountains (near Hagan). The author's discus-

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sion of the relation of these rocks to the Galisteo sandstone indicates that he regarded the coal beds which are above the marine Cretaceous as No. 4 (Pierre) or younger (although, according to Stevenson, he placed them in No. 3).

(P. 1000) The Cretaceous coal beds extending from Nacimiento Mountains northward are described.

(Pp. 1007-1008) A section is given in which coal is shown in Cretaceous No. 3, at Cristone, overlain by marine rocks, with fossils supposed to indicate Cretaceous No. 4.

37. 1875. COPE, EDWARD D.: The classification and distribution of the Cretaceous deposits of the West.

Vertebrata of the Cretaceous formations of the West, United States geological survey of the Territories, F. V. Hayden in charge, vol. II, pp. 15-41, 4°. Washington, 1875.

(P. 25) Brief reference is made to the Cerrillos coal beds.

38. 1875. COPE, EDWARD D.: The Geology of New Mexico.

Philadelphia Acad. Sci., Proc. (vol. 27), pp. 263-267. 1875. Am. Jour. Sci., 3d series, vol. 10, pp. 152-153. 1875.

(P. 264) Reference is made to the age of the Galisteo sandstone. (P. 267) A section of the rocks west of "Sierra Madre" is given, including both Cretaceous and Tertiary formations.

39. 1875. COPE, EDWARD D.: On the Cretaceous beds of the Galisteo.

Philadelphia Acad. Sci., Proc., for 1875 (vol. 27), pp. 359-360. 1875.

The author discusses Stevenson's paper on "Geological relations of the lignitic group of the Cretaceous," and refers the Galisteo formation to the Triassic on the supposition that former observers had inverted the section.

40. 1875. HOWELL, E. E.: Report on the geology of portions of Utah, Nevada, Arizona, and New Mexico, examined in 1872 and 1873.

Geographical and geological explorations and surveys west of the 100th meridian, Wheeler in charge, Report, vol. 3, geology, pp. 227-301, 4°. Washington, 1875.

(Pp. 275-280) Coal measures in Arizona, Utah, and western New Mexico are correlated with those "east of Mount Taylor" (the southeastern part of the San Juan Basin).

41. 1875. LOEW, OSCAR: Report on the mineralogical, agricultural, and chemical conditions observed in portions of Colorado, New Mexico, and Arizona. (Including analyses of soils and a chapter on "The eruptive rocks of Arizona and New Mexico.")

Geographical and geological explorations and surveys west of the 100th meridian, Wheeler in charge, Report, vol. 3, geology, pp. 569-661, 4°. Washington, 1875.

(Pp. 632-635) An analysis of the anthracite from Placer Mountain (Cerrillos field) is given; also an analysis of bituminous coal from the Rio Puerco near Nacimiento.

(P. 635) The anthracite coal is said to have been mined "40 years ago" (that is, about 1835).

The coal-bearing rocks are referred to the Cretaceous.

No. Date.

42. 1875. LOEW, OSCAR: Geological and mineralogical report on portions of Colorado and New Mexico.

Geographical explorations and surveys west of the 100th meridian, by Wheeler, annual report. Annual Report of the Chief of Engineers for 1875, part II, Appendix LL, pp. 1017-1036. Washington, 1875.

(Appendix LL is published in separate form, pp. 1-196. 1875.)

(Pp. 1023-1026) Cretaceous coal measures west of Nacimiento Mountains are described; also (p. 1027) those of the Rio Puerco field.

(P. 1028) The anthracite at Placer Mountain was examined; also the coal in Tijeras Canyon and other New Mexico localities.

43. 1876. MEEK, F. B.: Descriptions of the Cretaceous fossils collected on the San Juan exploring expedition under Macomb.

Report of expedition from Santa Fe, New Mexico, to the junction of the Grand and Green rivers of the Great Colorado of the West, in 1859, under Macomb; geological report by Newberry, pp. 119-133, plates, 4°. Washington, 1876.

The fossils described in this report were collected by Newberry in 1859 from the Cretaceous rocks of western New Mexico and Colorado.

(Pp. 121-122) Meek agrees with Newberry in correlating the "Lower Cretaceous" of the latter with the Dakota of the Upper Missouri Cretaceous section, the "Middle Cretaceous" with the Benton and Niobrara formations, and the "Upper Cretaceous" except the highest beds, which were regarded as probably Tertiary, with Pierre and Fox Hills.

44. 1876. NEWBERRY, JOHN S.: Geological report. Report of expedition from Santa Fe, New Mexico, to the junction of the Grand and Green rivers of the Great Colorado of the West, in 1859, under the command of Capt. J. N. Macomb, pp. 9-118, map. plates, 4°. Washington, 1876.

Abstract, Am. Jour. Sci., 3d series, vol. 13, pp. 220-221 (⅔ p.). 1876.

The Cretaceous is subdivided into three groups; the lowest or "Lower Cretaceous" includes the Dakota of other writers; the "Middle Cretaceous" is made equivalent to Benton and Niobrara, and the "Upper Cretaceous" to the Pierre and Fox Hills (including beds at the top that later proved to be Tertiary).

(P. 38) "Triassic rocks containing . . . silicified trunks of coniferous trees" are reported east of Cerrillos. (The silicified trees east of Cerrillos described by later writers are in the Galisteo sandstone.)

(Pp. 38 and 51) Near the mouth of Galisteo Creek, and also east of the town of Galisteo, fossil leaves said to be of Cretaceous age were found in yellow sandstone below the marine Cretaceous shale. (The description seems to indicate that these may be in rocks older than the Dakota of the present paper.)

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The coal beds at the base of Placer Mountain (the Mesaverde near Madrid) are referred to "Middle Cretaceous," and the bituminous coal is described as changed to anthracite by igneous intrusion.

(Pp. 67-71) In northern New Mexico (north of Jemez Mountains) the three subdivisions of the Cretaceous were recognized and traced westward through southwestern Colorado. The rocks near Sierra del Navajo (near the Colorado-New Mexico line) are described as "Middle" and "Upper Cretaceous." (The Mesaverde, Lewis, and "Laramie" formations of later writers.)

(P. 117) The "Brown sandstones and beds of lignite" near Nacimiento are referred to "Middle Cretaceous." (These are clearly the Mesaverde rocks of later writers.)

45. 1877. Cope, E. D.: Report on the extinct Vertebrata obtained in New Mexico by parties of the expedition of 1874.

United States geographical surveys west of the 100th meridian, Wheeler in charge, Reports, vol. 4, paleontology, 370 pages, plates 22-83, 4°. Washington, 1877.

Abstract, Am. Jour. Sci., 3d series, vol. 15, p. 56 (½ p.). 1878.

(Pp. 1-13) The Cretaceous west of Nacimiento and Gallinas Mountains is described and a cross-section given showing coal in "Cretaceous No. 3" (probably the Mesaverde), succeeded after a covered interval by Puerco.

(Pp. 13-25) The relations of the Eocene to the Cretaceous are discussed at some length.

46. 1877. Hayden, F. V.: United States geological and geographical surveys of the Territories; geological and geographical atlas of Colorado and portions of adjacent territory, by F. V. Hayden, folio 22, double folio atlas sheets, 35 by 22¾ inches. Washington, 1877 (second edition 1881).

Detailed geologic sheets, by Endlich, W. H. Holmes, Peale, Marvine, and C. A. White.

The Cretaceous and younger formations mapped in northwestern New Mexico are Dakota, Colorado (including Benton and Niobrara), Fox Hills (including Fox Hills proper and Pierre), Laramie, and Wasatch.

The marine shale (apparently both Mancos and Lewis), in northern New Mexico west of the Rocky Mountains, is mapped as Colorado shale. The coal-bearing rocks (apparently including both Mesaverde and "Laramie" and probably including also some of the Tertiary) are mapped as Fox Hills. The Wasatch is mapped as resting on the Fox Hills at the eastern margin of the San Juan Basin and on the Laramie farther to the west near Durango and elsewhere.

47. 1877. Macfarlane, James: Coal regions of America, their topography, geology, and development, xvi, 676 pages, 25 maps, New York, 1783, 2d edition; New York, 3d edition, xvi, 700 pages, maps, plates. New York, 1877.

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(Pp. 72-76) The author describes the coal beds of the Cerrillos field, and mentions those of the Rio Puerco and other New Mexico fields.

48. 1877. WHITE, CHARLES A.: Report on the invertebrate fossils collected in portions of New Mexico and Arizona by parties of the expeditions of 1871, 1872, 1873, and 1874. United States geographical surveys west of the 100th meridian, in charge of Wheeler, Reports, vol. 4, paleontology, part 1, 219 pages, plates 1-21, 4°. Washington, 1877.

Abstract, Am. Jour. Sci., 3d series, vol. 12, pp. 62-63 (⅔ p.). 1876.

The Cretaceous is not subdivided in this report. Several of the fossils described are from the Rio Puerco and neighboring regions.

49. 1878. LESQUEREUX, LEO: "The lignitic formation of North America" and "Descriptions of the Tertiary fossil plants."

United States geological and geographical survey of the Territories, F. V. Hayden in charge. Contributions to the fossil flora of the western Territories, parts 1 and 2, the Tertiary flora, by Leo Lesquereux, pp. 3-366, 15 plates, 4°. Washington, 1878.

Reviewed by E. D. Cope, Am. Nat., vol. 12, pp. 243-246. 1878.

(P. 314) The fossil plants from Placière (Cerrillos field) are included in the Tertiary flora. They are *Palmocarpon compositum* Lx.; *Carpites ligatus* Lx.; *Palmocarpon mexicanum* Lx.; *Carpites spiralis* Lx.

The formation (the Mesaverde of the Cerrillos field) is placed in the "first group," together with those in the Raton, Canyon City, Denver, and other coal fields.

50. 1879. COPE, EDWARD D.: The relations of the horizons of extinct Vertebrata of Europe and North America.

United States geological and geographical survey of the Territories, F. V. Hayden in charge, Bull., vol. 5, pp. 33-54. Washington, 1879.

(P. 50) Puerco (?) is shown as occurring above Laramie.

(P. 52) The Puerco marls first observed by Cope in 1874 were referred by Endlich in 1875 "to the lowest place in the Tertiary series, but the absence of fossils renders it difficult to conclude whether they belong here or in the Laramie series."

51. 1879. STEVENSON, JOHN J.: Geology of Galisteo Creek, New Mexico. Am. Jour. Sci., 3d series, vol. 18, pp. 471-475. 1879.

(P. 471) The coal beds north of Placer Mountain (Cerrillos field) are referred to the Laramie, and the underlying shale exposed near the town of Galisteo to the Pierre, Niobrara, and Benton.

The Galisteo sandstone is described as lying unconformably on beds ranging from "Laramie" to Dakota. (This probably is not the Galisteo of other writers.)

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52. 1881. STEVENSON, JOHN J.: Note on the Laramie group of southern New Mexico. Am. Jour. Sci., 3d series, vol. 22, pp. 370-372. 1881.

(P. 370) The statement is made that the "Laramie" beds are practically continuous from Galisteo Creek southward for 150 miles. (This is an error probably arising from the fact that coal occurs near a "San Pedro," about 10 miles south of the Galisteo, and also near another "San Pedro," about 150 miles to the south. The coal near San Pedro and San Antonio referred to by J. M. Robinson, whom Stevenson quotes, is probably the coal of the Tijeras field, but it is not certain how much of the description refers to this field and how much to the Carthage field near the "San Pedro" farther to the south.)

(P. 371) *Ostrea congesta* was observed "high up in the Laramie" of the Cerrillos field, and *Ostrea glabra, Anomia, Corbula 3* species, *Camptonectes* ?, and *Tellina* ? were obtained from the coal measures near San Pedro (probably from the Tijeras field) and identified by R. P. Whitfield.

53. 1881. STEVENSON, JOHN J.: Report on geological examinations in southern Colorado and northern New Mexico during the years 1878 and 1879. United States geographical surveys west of 100th meridian, in charge of G. M. Wheeler, Reports, vol. III, Supp., 420 pages, plates, 3 maps, 4°. Washington, 1881.

(Pp. 126-130) The "Galisteo coal field" (Cerrillos field) is briefly described and a detailed section of the coal-bearing rocks near the "western edge of area" is given, and the coal-bearing rocks are referred to the Laramie.

(P. 132) The subdivisions of Lower, Middle, and Upper Cretaceous are adopted, but Upper Cretaceous is here made equivalent to No. 5 (Fox Hills) and a part of No. 4 (Pierre), and Middle Cretaceous is made to include part of No. 4. On the maps Middle Cretaceous is labeled *Colorado.*

(P. 133) The coal beds of the Galisteo area are correlated directly with those of southern Colorado (Trinidad field) and with those of northern Colorado (Denver field) and Wyoming.

(P. 145) The writer states that Newberry regarded the coal beds near Chama and farther to the north and west as younger than those of the "Galisteo coal beds."

(P. 145) The Galisteo coal beds are correlated with Newberry's Upper Cretaceous of the Chama region (Newberry himself had referred them to Middle Cretaceous).

Cope's description of the rocks near Chama in the Wheeler reports (Nos. 26 and 36 of this list) is quoted as proof that Cope was describing the Upper Cretaceous of Newberry. Stevenson uses this for correlating with his Laramie. (P. 155) *Inoceramus* and *Ostrea* were found in the "Laramie" of the Galisteo area.

(Pp. 159-162) The Galisteo sandstone is referred to the Tertiary. (The description and the mapping indicates that the writer's Galisteo is quite different from the Galisteo of other

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authors and probably younger, for it lies with marked unconformity on older rocks. The Galisteo sandstone of other authors is evidently regarded as a part of Stevenson's "Laramie;" see author's figure 49.) (Pp. 328-346) Detailed descriptions and sections of the coal-bearing rocks are given.

54. 1881. STEVENSON, JOHN J.: United States geographical surveys west of the 100th meridian, Atlas. 1881.

For geology of New Mexico localities see Atlas sheets Nos. 69(B), 69(D), 70(A), 70(C), 77(B), 78(D).

55. 1882. COPE, EDWARD D.: The Tertiary formation of the central region of the United States. Am. Nat., vol. 16, pp. 177-195, plate. 1882.

The coal beds near Gallinas Mountains, New Mexico, are mentioned (p. 180) and a section farther north, including the coal measures, near the Colorado-New Mexico line, is described (p. 181).

56. 1882. STEVENSON, JOHN J.: Notes on the coal field near Canyon City, Colorado. Am. Phil. Soc., Proc., vol. 19, pp. 505-521. 1882.

Abstract, Am. Jour. Sci., 3d series, vol. 23, p. 152 (½ p.). 1882.

Brief reference is made to the coal measures on Galisteo Creek (Cerrillos field).

57. 1885. COPE, EDWARD D.: The Vertebrata of the Tertiary formations of the West, book 1, United States geological survey of the Territories, F. V. Hayden in charge, Report, vol. 3, xxxv, 1009 pages, 75 plates, 4°. Washington, 1884.

Reviewed, Science, vol. 5, pp. 467-469. 1885.

(P. 42) In the table of formations Puerco and Laramie are included under post-Cretaceous, although it is stated (p. 4) that the Puerco belongs to the "Tertiary rather than the post-Cretaceous," and Fox Hills is used as a group name to include "Fort Pierre" and "Fox Hills" proper. A cross-section west of Gallinas Mountains is given, showing "lignite" below "Fox Hills."

58. 1885. COPE, EDWARD D.: Relations of the Puerco and Laramie deposits. Am. Nat., vol. 19, pp. 985-986. 1885.

Observations from David Baldwin's notes are quoted, supplementing previous observations by the writer and others. The Laramie is said to overlie the Fox Hills, to be 2,000 feet thick at Animas City, New Mexico, and to contain characteristic Dinosaurs. The Puerco overlies the Laramie with apparent conformity, but is faunally distinct. It is sometimes included with the Laramie in post-Cretaceous series."

59. 1885. DUTTON, C. E.: Mount Taylor and the Zuni plateau. U. S. Geol. Surv., J. W. Powell, Director, 6th Annual Report, 1884-'85, pp. 106-198, plates 11-22. Washington, 1885.

Abstracts, Am. Jour. Sci., 3d series, vol. 34, pp. 155-157, 1887; Science, vol. 10, pp. 317-318, 1887.

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The Cretaceous is not subdivided for purposes of mapping in this paper. Observations were extended eastward to include a part of the valley of the Rio Puerco, but attention is directed principally to the igneous rocks, and little information is given as to the sedimentary formations of this valley.

60. 1885. STEVENSON, JOHN J.: Some notes respecting metamorphism. Am. Phil. Soc., Proc., vol. 22, pp. 161-166. 1885.

Abstract, Am. Jour. Sci., 3d series, vol. 29, p. 414 (½ p.). 1885.

(P. 166) Brief reference is made to the anthracite coal of Placer Mountain (Cerrillos field) and to the metamorphosed coal near Trinidad and near Raton.

61. 1886. WHITE, CHARLES A.: On the relation of the Laramie molluscan fauna to that of the succeeding fresh-water Eocene and other groups. U. S. Geol. Surv., Bull., No. 34, pp. 391-442, 5 plates. Washington, 1886.

Abstracts, Science, vol. 10, pp. 126-127, 1888; Popular Sci. Monthly, vol. 33, p. 420 (½ col.), 1888.

The relation of Laramie and Puerco is discussed and some of the invertebrates from the Puerco near Nacimiento are described.

62. 1889. STEVENSON, JOHN J.: The Mesozoic rocks of southern Colorado and northern New Mexico.

Am. Geol., vol. 3, pp. 391-397. 1889.

(Pp. 391-392) The coal-bearing rocks of the Canyon City, Trinidad, Raton, and Galisteo (Cerrillos) coal fields are referred to the Laramie. Rocks of Fox Hills age are supposed to occur below the coal near Canyon City and Trinidad, Colorado, but to thin out farther to the south and are "supposed to be absent" in the Galisteo area.

63. 1890. COPE, EDWARD D.: (Remarks on the age and stratigraphic components of the Laramie group.)

Geol. Soc. Am., Bull., vol. 1, p. 532, 1890; Am. Nat., vol. 24, p. 569, 1890.

The Puerco containing "about 100 species of mammalia" is said to rest on the Laramie, which also contains some mammals.

64. 1890. NEWBERRY, JOHN S.: The Laramie group. Its geologic relation, its economic importance, and its fauna and flora.

New York Acad. Sci., Trans., vol. 9, pp. 27-32. 1890.

Abstract (by author), Geol. Soc. Am., Bull., vol. 1, pp. 524-527, 527-528, 1890, with discussion by J. B. Tyrrell, L. F. Ward, J. J. Stevenson, and E. D. Cope, pp. 527-532.

Other abstracts, Am. Geol., vol. 5, pp. 118 (¼ p.); Am. Nat., vol. 24, pp. 856-857 (¼ p.).

The coal beds of New Mexico enter into the discussion only incidentally.

65. 1890. STEVENSON, JOHN J.: (Remarks on the differentiation of the Colorado group in Colorado and New Mexico.)

No. Date.

Geol. Soc. Am., Bull., vol. 1, p. 532 (⅔ p.), 1890; Am. Nat., vol. 24, pp. 568-569, 1890.

Discussion of paper by J. S. Newberry, "The Laramie group." The writer states that the Fox Hills thins out to the south in New Mexico, but that the other Cretaceous formations continue around the mountains to the Rio Grande. (These formations are not known to exist over a large area at the southern end of the mountains.)

66. 1890. WARD, LESTER F.: (Remarks on the age of the Laramie group.) Geol. Soc. Am., Bull., vol. 1, pp. 529-532, 1890; Am. Nat., vol. 24, pp. 564-568, 1890.

Discussion of paper by J. S. Newberry on "The Laramie group." Discussion in which the coal beds of New Mexico are assumed to be Laramie.

67. 1893. EMMONS, SAMUEL FRANKLIN: Excursion to the Canyon of the Colorado. Itinerary, Denver, Colorado, to Albuquerque, New Mexico.

Int. Cong. Geol., Compte Rendu, 5th session, pp. 464-468. 1893.

The reference of the coal beds near Ortiz in the Cerrillos field to Laramie is accepted.

68. 1895. OSBORN, H. F., and EARLE, CHARLES: Fossil mammals of the Puerco beds. Am. Mus. Nat. Hist., Bull., vol. vii, pp. 1-70, figs. 1-21. 1895.

The coal beds below the Puerco are assumed to be Laramie, and the Puerco is said to contain "several Laramie reptiles" (p. 4).

69. 1896. STEVENSON, JOHN J.: The Cerrillos coal fields near Santa Fe, New Mexico. N. Y. Acad. Sci., Trans., vol. xv, pp. 105-122. 1896.

Abstract, Geol. Soc. Am., Bull., vol. vii, pp. 525-527; Science, new ser., vol. iii, pp. 392-394. 1896.

(P. 111) The statement is reiterated that the Fox Hills stage of the Rocky Mountain region is not represented in this area and the coal beds are assumed to be Laramie. Sections of the coal-bearing rocks are given, the characteristics of the coal described, and several analyses of the coal are given. The metamorphosis of the bituminous coal into anthracite is discussed.

70. 1897. FLEMING, JOHN W.: (Coal mines of New Mexico.) Report of the Governor of New Mexico to the Secretary of the Interior. Washington, 1897, pp. 91-115.

The report contains a geologic section of the rocks exposed near Madrid in the Cerrillos coal field. Coal mines in northern New Mexico near Monero are referred to.

71. 1898. FLEMING, JOHN W.: (Coal mines of New Mexico.) Report of the Governor of New Mexico to the Secretary of the Interior. Washington, 1898, pp. 56-86.

The report contains a geologic section of rocks exposed near Madrid in the Cerrillos coal field.

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The mines at Monero are described, where three beds of coal ranging in thickness from 3 feet 6 inches to 3 feet 10 inches have been opened.

72. 1898. HERRICK, C. L.: The geology of the San Pedro and the Albuquerque districts (New Mexico).

Denison Univ., Sci. Lab., Bull., vol. xi, pp. 93-116, pl. xiii. 1898.

The coal-bearing rocks outcropping on the Rio Puerco (p. 97) and those of the Tijeras field (pp. 108-109) are described as Cretaceous.

(P. 112) The coal beds of the Cerrillos field at Waldo, Madrid, and Omera are briefly mentioned. A sketch map of the geologic formations accompanies the paper.

73. 1898. SPENCER, ARTHUR COE: The Upper Cretaceous section in southwestern Colorado. Abstract, Science, new ser., vol. vii, p. 143 (¼ p.). 1898.

The statement is made that above the Dakota "comes a series of shales, known to embrace the Benton, Niobrara, and a part of the Pierre, which can not be divided on lithologic grounds. The upper part of the section . . . consists of massive sandstones in which both the Fox Hills equivalent and that of the Laramie may prove to be present." No mention is made of the Lewis shale.

74. 1899. FLEMING, JOHN W.: (Coal mines of New Mexico.) Report of the Governor of New Mexico to the Secretary of the Interior. Washington, 1899, pp. 164-209.

The coal mines near Madrid in the Cerrillos field are described and the geologic relations of the coal beds shown by columnar section.

The mines at Monero are also described.

75. 1899. CROSS, WHITMAN: U. S. Geol. Survey, Geol. Atlas of U. S., folio No. 60. 1899.

(Pp. 4 and 5) The coal-bearing rocks are described as the *Mesaverde* formation and are underlain by *Mancos* shale and overlain by *Lewis* shale.

(P. 4) The Lewis is described as about 2,000 feet thick. The occurrence of coal-bearing rocks above the Lewis is noted, but doubt is cast on their assignment to the Laramie.

(P. 5) The lower part of the Mancos shale contains the following characteristic Benton fossils: *Gryphæa newberryi; Ostrea lugubris; Ostrea congesta; Inoceramus labiatus; Inoceramus fragilis; Inoceramus dimidius; Prionocyclus macombi; Baculites gracilis; Scaphites warreni; Anatina* sp.?; *Plicatula* n. sp.

The upper part of the Mancos contains the following Pierre fossils (this revised list has been prepared for the present paper by T. W. Stanton): *Inoceramus barabini; Inoceramus* sp.; *Inoceramus sagensis; Syncyclonema rigida; Scaphites* sp.;

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Baculites sp., a large form resembling *Baculites ovatus* or *Baculites compressus; Arca* sp.?; *Turritella* sp.?

76. 1900. Fleming, John W.: Report of the mine inspector for the Tertiary of New Mexico.

Report of the Governor of New Mexico to the Secretary of the Interior. Washington, 1900, pp. 279-314.

The mines of the Cerrillos coal field are described and those of Monero are mentioned.

77. 1900. Herrick, C. L., and Johnson, D. W.: The geology of the Albuquerque sheet (New Mexico).

Denison Univ. Sci. Lab., Bull., vol. xi, art. ix, pp. 175-239, pls. xxvii-lviii. 1900.

Hadley Lab. Univ. of New Mexico, Bull., vol. ii, pt. i, 1900, pp. 1-67, 32 pls., colored geologic map in pocket. 1900.

(Pp. 187-188) A *Gastropod zone* is described as occurring about 40 feet above the Dakota sandstone, followed upward by the *Tres Hermanos sandstone* and a *Concretion zone*, which "abounds in large ammonites shells and large species of *Pinna* and *Baculites*." This zone was recognized, according to these writers, near Cabezon, about 20 miles to the northwest and near Una del Gato (Hagan field), about 30 miles to the east. These three zones are close together, and from them, in the Rio Puerco, Hagan, and Tijeras fields, the following fossils were collected: [It is not always possible to determine from the descriptions when the authors refer to the Concretion zone and when to the Cephalopod zone. Hence it is possible that some of the following species may have come from the Cephalopod zone.] *Ostrea translucida* M. & H.; *Exogyra læviscula* Roemer; *Exogyra columbella* Meek; *Mactra* (?) *subquadrata* H. & J.; *Tapes cyrimeriformis* Stanton; *Caryates veta* Whitfield; *Pholadomya subventricosa* M. & H.; *Liopistha concentrica* Stanton; *Camptonectes symmetricus* H. & J.; *Dosinia* sp.; *Chemnitzia* sp.; *Sigaretus textilis* Stanton; *Baculites gracilis Shumard*?; *Prionotropis woolgari* Mantell; a thick shale (the principal part of the Mancos) occurs above the *Concretion zone*, but its thickness is not given. Apparently the space occupied by it is represented by the hiatus in the section east of Prieta Mesa, given in plate 22. (Johnson has stated personally to the present writer that the shale between the "*Concretion zone*" and the "*Cephalopod zone*" was roughly estimated at 1,000 feet.) A *Cephalopod zone* occurs about 100 feet from the top of this shale (the present writer found this zone to be about 300 feet from the top), and above it occurs the *Punta de la Mesa sandstone*—the basal member of the yellow sandstones described as the "*Prieta Series*." These sandstones, together with the Cephalopod zone, are referred to the Fox Hills. [The sandstones are now referred to the Mesaverde and the Cephalopod zone to the Benton.] From them the following fossils were identified: *Ostrea lugubris* Conrad; *Ostrea sannionensis* White; *Gryphæa*

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vesicularis Lam.; *Inoceramus fragilis* H. & M.; *Pinna petrina* White; *Rostellites ambigua* Stanton; *Buchiceras swallovi* Shumard; *Sphenodiscus lenticulare* Owen; *Placenticeras placenta* De Kay; *Placenticeras costata* H. & J.; *Pholadomya subventricosa; Scaphites nodosus* M. & H.; *Scaphites* sp. [The description of locality is vague. The Scaphites probably are from near the middle of the Mancos shale.]

The upper part of the "Prieta series" contains marine shells said to be of Fox Hills age and fossil plants "not identifiable with familiar Laramie species." The following fossils were collected from these coal-bearing rocks in the Rio Puerco, Hagan, and Tijeras fields: *Ostrea prudentia* White; *Ostrea franklini* Coquand?; *Exogyra texana* Roemer; *Exogyra winchelli* White; *Mactra pulchella* H. & J.; *Tellina* (?) *perlata* H. & J.; *Tellina equilateralis* Meek; *Idonarca* (?) *depressa* White; *Cardium pauperculum* Meek; *Cardium* sp.; *Legumen* (?) *oppressum* Conrad; *Chemnitzia coalvillensis* Meek; *Gyrodes depressa* Meek; *Pyropsis bairdi* M. & H.; *Rostellites dalli* Stanton; *Valutomorpha* (?) *nova-mexicana* H. & J.; *Harpa* (?) *occidentalis* H. & J.; *Baculites asper* Morton; shark's teeth; plants.

(P. 17) Tertiary beds "with remains of vertebrates which we presume to be representatives of lower Tertiary strata" lie stratigraphically above the coal-bearing rocks on the Rio Puerco.

78. 1900. Herrick, C. L.: Report of a geological reconnaissance in western Socorro and Valencia counties, New Mexico.

Am. Geol., vol. xxv, pp. 331-346, pls. viii-lx. 1900.

This paper supplements to some extent the information given in the description of the Albuquerque sheet (p. 338). A section measured east of Prieta Mesa is given, in which the *Cephalopod zone* is placed only about 100 feet above the *Tres Hermanos sandstone* (this Cephalopod zone seems to be the Concretion zone of Herrick and Johnson). The coal-bearing sandstones and shales (Mesaverde) are about 1,600 feet thick and are overlain by Tertiary.

79. 1901. Herrick, C. L.: Applications of geology to economic problems in New Mexico. Int. Mg. Cong., 4th session, Proc., pp. 61-64. 1901.

(P. 64) Attention is called to the fact that some of the New Mexico coal-bearing rocks formerly supposed to be Laramie contain *Ostrea glabra* and are overlain by marine Cretaceous beds "with fossils like those of the upper Fox Hills group."

80. 1901. Sheridan, Jo E.: Report of the mine inspector for the Territory of New Mexico.

Report of the Governor of New Mexico to the Secretary of the Interior. Washington, 1901, pp. 309-351.

The coal mines of the Cerrillos field and those at Monero are described.

81. 1902. Lee, W. T.: The Morrison shales of southern Colorado and northern New Mexico.

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Jour. Geol., vol. 10, pp. 36-58, 7 figs. 1902.

The Exeter sandstone is named and described in this paper.

82. 1902. STORRS, L. S.: The Rocky Mountain coal fields. U. S. Geol. Surv., 22d Ann. Rept., pt. 3, pp. 415-471, 2 pls., 1 fig. 1902.

The coal beds of the San Juan Basin and of the Cerrillos and Hagan fields are referred to the Laramie and the coal of the latter two is said to lie "under the Tertiary beds."

83. 1903. JOHNSON, D. W.: Geology of the Cerrillos Hills, New Mexico. Part I, General geology; part II, paleontology; part III, petrography.

School of Mines Quart., vol. 24, pp. 303-350, 7 pls., 7 figs.; pp. 456-500, 10 pls,, 6 figs,, 1903; pp. 173-246, 14 pls., 1903; vol. 25, pp. 69-98, 5 pls., 1903.

The reports result from the work done in 1899-1902. Among others the following propositions are supported:

(1) The Santa Fe marls of Hayden . . . represent the time from the early Loup Fork Tertiary to the Recent period.

(2) The Galisteo Group of Hayden consists of red beds of late Cretaceous, probably Laramie age.

(3) The coal series, or Madrid Group, is of Fox Hills age.

(4) Pierre, Benton, and probably Dakota and Jura-Triassic beds, are also present in the district.

(Vol. 24, pp. 336-338) The Galisteo sandstone is referred doubtfully to the Laramie and is described as consisting of red sedimentary rocks similar lithologically to the older "Red Beds," and lying conformably (? see discussion on this point in the present paper) on the Madrid group. They contain fossil wood which, according to F. H. Knowlton, indicates a species of *Quercus* and is evidently of Upper Cretaceous or later age.

(Pp. 338-344) The Madrid Coal Group is described as 1,500 to 2,000 feet thick. The coal is said to be in the lower part of this group. The author's figure 5 makes the base of the group rest on the lowest sheet of intrusive igneous rock at Madrid and places the rocks below this sheet in the Pierre. (This would place in the Pierre below the Madrid group a considerable thickness of sandstone and several thin beds of coal which obviously belong in the Madrid or coal-bearing formation.) The base of the Madrid group is obviously drawn but little below the coals that have been mined, for the writer states (p. 340) that "the coal in the *lower portion* of the Madrid group has proven of great interest to geologists, and so many references have been made to it," etcetera.

(Pp. 344-347) The Pierre group is described as consisting of shale and sandstone. A section (p. 346) places 162 feet of sandstone above the dark-colored shale (Mancos) in the Pierre.

(P. 347) No undoubted Niobrara was found, but the Benton and Dakota occur.

(Pp. 477-493) The economic features of the coal are described. Fossil leaves, identified by Knowlton (p. 178, Paleontology) as

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Ficus rhamroides Knowlton, *Ficus uncata* Lesquereux, *Quercus* ? sp., and *Aralia* ? sp. were found above the highest coal bed east of Madrid.

In some places fossils characteristic of the Colorado and Montana groups seem to occur together (p. 182) as follows: *Inoceramus labiatus* Schloth. (Colorado form); *Stantonoceras pseudocastatum* Johnson (Colorado form); *Astarte evansi* H. and M. (Montana form); *Placenticeras placenta* De Kay (Montana form); *Baculites anceps* Lamarck.

At another locality (p. 183) *Ostrea lugubris* Conrad (Colorado form) and *Astarte evansi* H. and M. (Montana form) were found together.

The following faunas of the Cerrillos region are described:

Pierre fauna—*Lingula subspatulata* H. and M.; *Ostrea anomioides* var. *nanus* Johnson; ?*Ostrea congesta* Conrad; *Inoceramus simpsoni* Meek; *Inoceramus vanuxemi* M. and H.; *Inoceramus balchii* M. and H.; *Inoceramus cripsi* var. *barabini* Morton; *Inoceramus irregularis* Johnson; *Inoceramus* sp.; *Endocostea typica* Whitfield; *Endocostea brooksi* Johnson; *Arca madridensis* Johnson; *Trigonarea obliqua* Meek; *Nucula subplana* M. and H.; *Astarte evansi* (H. and M.) Whitfield; *Protocardia rara* E. and S.; *Cyprimeria* ? *sulcata* Johnson; *Solen cuncatus* Gabb; *Corbula mematophora* var. *fitchi* Johnson; *Natica* sp.; *Turritella galisteoensis* Johnson; *Rostellario* ? *texana* Conrad; *Tritonium kanabense* Stanton; *Admetopsis* ? *elevata* Johnson; *Helicoceras pariense* White; *Baculites anceps* Lamarck; *Baculites* sp.; *Placenticeras placenta* De Kay; *Placenticeras* ? sp.; *Placenticeras* ? *intermedium* Johnson; *Placenticeras* ? *rotundatum* Johnson; *Stantonoceras guadaloupæ* Roemer; *Beryx* sp.

Benton fauna—*Ostrea lugubris* Conrad; *Inoceramus fragilis* H. and M.; *Inoceramus labiatus* Schloth.; *Inoceramus dimidius* White; *Inoceramus stongi* Johnson; *Acmæa cerrillosensis* Johnson; *Scurria coniformis* Johnson; *Rostellites dalli* var. *wellsi* Johnson; *Rostellites ambigua* Stanton; *Prionocyclus wyomingensis* Meek; *Prionocyclus macombi* Meek; *Prionocyclus* sp.; *Prionotropis woolgari* Mantell; *Scaphites warreni* M. and H.; *Beryx* sp.; *Baculites anceps* Lamarck; *Stantonoceras pseudocostatum* Johnson.

84. 1903. Reagan, Albert B.: Geology of the Jemez-Albuquerque region, New Mexico. Am. Geol., vol. 31, pp. 67-111, 7 pls. 1903.

See also Ind. Acad. Sci., Proc., pp. 187-198. 1903.

A geologic sketch map, showing the distribution of the formations from Cabezon eastward to Hagan, is given.

(P. 79) The author's *Fox Hills* includes the sandy rocks below the coal; and the coal-bearing rocks, 500 feet thick, are described as "*Fort Union*" or "*Laramie*." His "Fox Hills" and "Fort Union" constitute the "Fox Hills" of Herrick and Johnson and the *Mesaverde* of later writers.

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(P. 81) The colored sediments lying unconformably on the coal-bearing rocks south of San Isidro (in the Rio Puerco field) are referred to the Puerco.

85. 1904. JONES, FAYETTE ALEXANDER: New Mexico mines and minerals. World's Fair edition, 1904. Santa Fe, New Mexico, the New Mexican Printing Company, 1904. 349 pp., 50 figs.

(P. 7) The New Mexico coal beds are referred to Fox Hills and Laramie. The coal of the Cerrillos field is referred to the Fox Hills.

86. 1904. KEYES, CHARLES ROLLIN: Unconformity of the Cretaceous on older rocks in central New Mexico. Am. Jour. Sci., 4th ser., vol. 18, pp. 360-362, 2 figs. 1904.

Cretaceous sandstone (2,000 feet thick) lying above rocks of Montana age (presumably the coal-bearing sandstones described in this paper as Mesaverde) are referred to the Laramie.

87. 1904. KEYES, CHARLES ROLLIN: The Hagan coal field (New Mexico). Eng. & Mg. Jour., vol. 78, pp. 670-671, 3 figs. 1904.

The Hagan coal field is described with sketch maps and geologic sections. A detailed section is given of the coal-bearing rocks measured at the Hagan mine.

88. 1904. SHERIDAN, JO E.: Annual report of the mine inspector for the Territory of New Mexico.

U. S. Mine Inspector for the Territory of New Mexico, Ann. Rept. to the Secretary of the Interior for the year ended June 30, 1904. Washington, 1904, 79 pp.

(Pp. 32-38) The coal beds of the Cerrillos, Una del Gato (Hagan), and Monero fields are described.

89. 1904. LAKES, ARTHUR: The coal fields of Colorado.

Colo. Sch. Mines, Bull., vol. 2, no. 2, pp. 11-23, 2 figs. 1904.

90. 1905. OGILVIE, IDA H.: The high altitude conoplain; a topographic form illustrated in the Ortiz Mountains (New Mexico).

Am. Geol., vol. 36, pp. 27-34, 1 pl. 1905.

The conoplain described lies across the eroded coal beds of the Cerrillos and Hagan fields.

91. 1905. SHERIDAN, JO E.: Annual report of the mine inspector for the Territory of New Mexico.

U. S. Mine Inspector for the Territory of New Mexico, Ann. Rept. to the Secretary of the Interior for the year ended June 30, 1905. Washington, 1905.

(Pp. 40–48) Describes the Cerrillos and Una del Gato (Hagan) coal fields.

92. 1905. STANTON, T. W.: Morrison formation and its relation with the Comanche series and the Dakota formation.

Jour. Geol. vol. XIII, pp. 657–669. 1905.

(P. 664) Some of the rocks in northeastern New Mexico and southeastern Colorado heretofore called Dakota are shown on fossil evidence to be Comanche.

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(P. 666) Near Canyon City, Colo., the shale which separates the two plates of so-called Dakota sandstone was found to contain a Comanche fauna.

93. 1906. GRIFFITH, WILLIAM: Kinds and occurrence of anthracite coal. Min. Mag., vol. 13, no. 3, pp. 214-221, March. 1906.

(P. 218) Brief reference is made to the Cerrillos coal.

94. 1906. JONES, FAYETTE A.: Mineral resources of New Mexico. Am. Min. Cong., 8th Ann. Sess., pp. 135-143. 1906.

(P. 143) Brief reference is made to the coal beds of New Mexico.

95. 1906. KEYES, CHARLES R.: Orotaxial significance of certain unconformities. Am. Jour. Sci., 4th ser., vol. 21, pp. 296-300, 2 figs., April, 1906.

A generalized section is given showing the position of certain unconformities in the sedimentary rocks of New Mexico (two of which—between "Dakotan and Coloradan," and between "Montanan and Laramian"—affect rocks described in the present paper, but which are not confirmed by the present writer).

96. 1906. KEYES, CHARLES ROLLIN: Geological section of New Mexico. Science, new ser., vol. 23, pp. 921-922, June 15, 1906.

A generalized geologic section is given.

97. 1906. LEE, WILLIS T.: The Engle coal field, New Mexico. U. S. Geol. Survey, Bull. no. 285, p. 240. 1906.

The coal beds of the Engle field contain numerous plant remains and rest on rocks containing a Benton fauna. Lying unconformably on the coal-bearing rocks are red sedimentary rocks similar in general appearance to the Galisteo sandstone of the Cerrillos field. *Triceratops* bones were found in these red rocks. The correlation of the coal with that at Cerrillos and Raton is suggested.

98. 1906. MERRILL, GEORGE P.: Contributions to the history of American geology. U. S. Nat. Mus., Ann. Rept. 1904, pp. 189-733, 37 pls., 141 figs. 1906.

Several brief sketches are given of the men who worked in New Mexico and of the results obtained by them. Chapter X is devoted to the Laramie question.

99. 1906. RITTER, ETIENNE A.: Les basin lignitiferes et houillers des Montagnes Rocheuses. Annales des Mines, 10° ser., t. 10, livr. 7, pp. 5-84. 1906.

(P. 52) The Fox Hills age for the Cerrillos coal measures is accepted.

100. 1906. SCHRADER, FRANK CHARLES: The Durango-Gallup coal field of Colorado and New Mexico. U. S. Geol. Survey, Bull. no. 285, pp. 241-258. 1906.

A map is presented outlining the north, east, and south sides of the principal part of the coal fields of the San Juan basin. Five groups of coal beds are mapped: (1) a *Colorado* group in the southwestern part of the field; (2) a *lower Montana* group—

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relation to the Mesaverde unknown—occurring also in the southwestern part of the field; (3) a *Mesaverde* group occurring on the north and east parts of the field; (4) an "*upper Montana* group—relation to the Mesaverde unknown"—occurring in the south and southeastern parts of the field; and (5) a "*Laramie*" group occurring in the northern and northeastern parts.

The "Laramie" is shown from Colorado as far south as Gallinas Mountains, New Mexico, and is the same as the "Laramie" of other writers; the Mesaverde extends as far south as the Puerco River. The upper Montana group occurs in the southeastern part of the field near Cabezon, and is the Mesaverde of later writers. The other groups occur only west of the area described by the writer.

(P. 251) The Chico Arroyo district, extending from Sierra Nacimiento to Mount Taylor, contains coal-bearing rocks 2,000 to 3,000 feet thick, which are said to lie unconformably on the Mesaverde and to contain fossils which indicate that they are younger than Mesaverde. These constitute the "upper Montana coal group." (The "Mesaverde" and the "upper Montana coal group" of Schrader together constitute the Mesaverde of Gardner and the present writer.)

101. 1906. SHERIDAN, Jo E.: Report of the mine inspector for the Territory of New Mexico to the Secretary of the Interior for the year ended June 30, 1906. Washington, Government Printing Office, 1906. 87 pp.

(Pp. 51-57) The Cerrillos and Una del Gato (Hagan) coal fields are described.

102. 1906. SHERIDAN, Jo E.: Present conditions and future prospects of the coal-mining industry in New Mexico.

Annual Report U. S. Mine Inspector for the Territory of New Mexico to the Governor of New Mexico, Santa Fe, 1906, 134 pp.

(Pp. 66-69) The coal mines at Monero are described. Three beds of coal varying from 3 to 4 feet in thickness are said to be worked.

(Pp. 70-78) The mines in the Cerrillos and Una del Gato (Hagan) fields are briefly described.

103. 1907. CAMPBELL, MARIUS R.: The Una del Gato coal field, Sandoval County, New Mexico, U. S. Geol. Survey, Bull. no. 316, pp. 427-430, 1 fig. 1907.

The Una del Gato (Hagan) field is described principally from an economic point of view. A section of the rocks measured by Charles R. Keyes near Sloan mine is given. The coals are correlated with those of the Cerrillos field, and the statement is made that "it is highly probable that they are Laramie."

104. 1907. LEE, WILLIS T.: Note on the red beds of the Rio Grande region in central New Mexico.

Jour. Geology, vol. 15, no. 1, pp. 52-58. 1907.

(P. 57) Coal-bearing rocks near Elephant Butte, New Mexico,

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are described as underlying red beds containing bones of *Triceratops*, which suggest late Cretaceous age. Red beds of similar appearance near Cerrillos, New Mexico, known as Galisteo sandstone have also been regarded as late Cretaceous, and the correlation of the two is suggested.

105. 1907. SHALER, MILLARD K.: A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado and New Mexico. U. S. Geol. Survey, Bull. no. 316, pp. 376-426, 2 pls. 1907.

The paper deals with the geology of the western part of the San Juan Basin.

106. 1907. SHERIDAN, Jo E.: Report of the mine inspector for the Territory of New Mexico to the Secretary of the Interior for the fiscal year ended June 30, 1907.

Washington, Government Printing Office, 1907, 48 pp.

(Pp. 33-36) The coal beds of the Cerrillos and Hagan fields are described.

107. 1908. CAMPBELL, M. R.: Coal fields of the United States. Map, with explanations. U. S. Geol. Surv. 1908.

108. 1908. JONES, FAYETTE A.: Epitome of the economic geology of New Mexico. Published by direction of the New Mexico Bureau of Immigration. 1908. 47 pp.

Brief references are made to the coal beds.

109. 1908. SHIMER, H. W., and BLODGETT, MILDRED E.: The stratigraphy of the Mount Taylor region, New Mexico. Am. Jour. Sci., 4th ser., vol. 25, pp. 53-67, 4 figs., January, 1908.

This paper is a report on observations made in 1906 in the Rio Puerco Valley south of Cabezon.

(P. 54) The "Gastropod Zone" near the base of the Cretaceous; the "Concretion (Septaria) Zone" (near the Tres Hermanos sandstone), and the "Cephalopod Zone" (near the top of the Mancos) of Herrick and Johnson were recognized, but most of the fossils collected are from the latter two zones, although one fossil, *Gryphæa newberryi* Stanton, was found below the "Septaria Zone."

(P. 56) The following fossils of Benton age were collected from the "Septaria Zone," about 8 miles southwest of Casa Salazar: *Placenticeras ? rotundatum* Johnson; ?*Prionocyclus wyomingensis* Meek; *Lima utahensis* Stanton; *Stantonoceras stantoni* Johnson; *Scaphites* sp.; *Turritella whitei* var. *stantoni* S. and B.; ?*Ostrea lugubris* Conrad.

(P. 57) The "Septaria Zone" of these authors is said to disappear under the surface a short distance north of Casa Salazar. (This fixes its horizon near the base of the thick shale above the Tres Hermanos sandstone.)

(P. 57) About seven miles southwest of Cabezon (supposed to be near the top of the Mancos shale), the following fossils were collected: *Trigonarca depressa* White; **Lucina* cf. *subundata* H. and M.; **Pteria linguiformis* (E. and S.); ***Solemya* ?

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obscura Stanton; *Pinna* sp.; ***Actæon propinquus* Stanton. (Those marked * are said to be of Pierre age, and those marked ** to be of Benton age.)

(P. 58) About 16 miles southeast of Cabezon (probably near the top of the Mancos shale) the following fossils were found: *Prionotropis woolgari* (Mantell); *Placenticeras placenta* (Dekay); *Astarte evansi* (H. & M.) Whitfield, and 7 miles farther southeast, at about the same horizon as those named above, the following were collected: *Gryphæa newberryi* Stanton; *Inoceramus labiatus* (Schlotheim); *Inoceramus dimidius* var. *labiatoides* S. and B.; ?*Yoldia subelliptica* Stanton; *Anomia propatoris* White; *Ostrea lugubris* Conrad; *Ostrea anomioides* var. *nanus* Johnson; *Cardium pauperculum* Meek; *Turritella whitei* var. *stantoni* S. and B.; *Lunatia concinna* (H. and M.); *Prionotropis hyatti* Stanton; *Prionotropis woolgari* (Mantell).

(Pp. 59-60) Evidence is given to the effect that there are two "Septaria zones" below the "Caphalopod zone" of Herrick and Johnson, which contain a fauna said to be "almost totally distinct from the Septaria fauna. The authors conclude that the strata yielding the fossils described vary in age from Benton to doubtful Pierre and "show a commingling of many species of the Colorado formations with a few of the Montana. This would apparently indicate an upper Fort Benton age for the beds unless we suppose that the apparent absence of clear water in this region during Niobrara times would cause the absence of the typical Niobrara fauna and the persistence of the Fort Benton fauna to Montana times. Under such a supposition, some of these intermediate strata would represent the Niobrara time, without the presence of the typical Niobrara fauna."

110. 1909. Gardner, James H.: The coal field between Gallina and Raton Spring, New Mexico, in the San Juan coal region.

U. S. Geol. Survey, Bull. 341, pp. 335-351, 1 pl. (map). 1909.

Two coal-bearing formations southwest of Nacimiento Mountains are described. They are the Mesaverde, which includes Schrader's "Upper Montana Group," and the "Laramie." These are separated by Lewis shale, which is said to be 2,000 feet thick near Gallina and only 250 feet thick on the Arroyo Torreons, about 30 miles to the southwest. Several geologic sections are given showing the relations of the coal beds to other rocks.

(P. 338) "At a point 10 miles north of Gallina a part of the (Mancos) becomes arenaceous and forms a hogback in the shale valley. This sandy bed is about 30 feet thick and about 275 feet below the top of the formation. It is no doubt the beginning of the sandstone and shale formation that increases in thickness toward the south and is coal-bearing on the south side of the (San Juan) basin."

111. 1909. Lee, Willis T.: Unconformity in the so-called Laramie of the Raton coal field, New Mexico.

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Geol. Soc. Am. Bull., vol. 20, pp. 357-368, 3 plates, 1 fig. 1909.

The paper presents evidence that the coal-bearing rocks of the Raton field are divisible into two formations, the lower one possibly older than Laramie and the upper one of post-Laramie age.

112. 1909. Lee, Willis T.: The Manzano group of the Rio Grande Valley, New Mexico. U. S. Geol. Survey, Bull. 389, pp. 5-40, 5 pls., 9 figs. 1909.

The paper includes geologic sections of the older rocks up to and including the Dakota sandstone in the Cerrillos and Hagan fields.

113. 1909. Stanton, T. W.: The age and stratigraphic relations of the "Ceratops beds" of Wyoming and Montana.

Washington Acad. Sci., Proc., Vol. XI, pp. 239-293. 1909.

(P. 274) The paper gives the names of invertebrates from the "Laramie" of southwest Colorado.

114. 1910. Darton, Nelson Horatio: A reconnaissance of parts of northwestern New Mexico and northern Arizona.

U. S. Geol. Survey, Bull. 435, 88 pp., 17 pls., 8 figs. 1910.

The geology along the Santa Fe Railway from Albuquerque westward is described. The Cretaceous consists of the following formations, given in descending order: *Laramie*, coal-bearing; *Lewis* shale; *Mesaverde*, coal-bearing; *Mancos* shale, locally coal-bearing; *Dakota* sandstone.

(P. 58) Gardner's results are accepted for the Nacimiento region and Herrick and Johnson's for the Rio Puerco region. Herrick's section in the Rio Puerco Valley (78, p. 338) is quoted with several changes, and the reference of the coal-bearing rocks including the "Punta de la Mesa sandstone" to the Fox Hills is accepted.

A section of rocks exposed at Laguna, west of the Rio Puerco coal field, was measured. The following fossils occur about 550 feet above the base of this section: *Exogyra columbella* Meek; *Gryphæa* sp., probably a variety of *Gryphæa newberryi; Avicula gastrodes* Meek ?; *Cardium, Panopea, Turritella, Rostellites*, and *Fusus* sp.

About 100 feet lower in the section the following species were collected: *Exogyra columbella* Meek; *Pecten* sp.; *Pinna petrina* White; *Inoceramus* ?, *Leda, Cardium*, and *Lucina* ? sp.; *Isocardia* n. sp.; *Cyprimeria* ? sp., *Corbula* sp.; *Liopistha* (Psilomya) *concentrica* Stanton; *Turritella whitei* Stanton; *Tritonium kanobense* Stanton; *Actæon, Cinulia, Turrilites* ?, or *Heteroceras* sp. Doctor Stanton is quoted as reporting that these fossils indicate a horizon in the Benton formation.

115. 1910. Gardner, James H.: Isolated coal fields in Santa Fe and San Miguel counties, New Mexico.

U. S. Geol. Survey, Bull. 381, pp. 447-451. 1910.

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A part of this paper is devoted to the "Omara Coal Field," and the coal beds at the Omara mine are correlated with those near Madrid. (These localities are at opposite extremities of the Cerrillos field.)

116. 1910. GARDNER, JAMES H.: The coal field between San Mateo and Cuba, New Mexico. U. S. Geol. Survey, Bull. 381, pp. 461-473, 1 pl. (map). 1910.

The coal-bearing formations of the southeastern part of the San Juan Basin are described as Mesaverde and "Laramie." A detailed section of the Mesaverde on Arroyo Torreons (p. 470) shows a thickness of 1,328 feet.

The statement is made (p. 462) that the Mesaverde "is now known to encircle the San Juan Basin. The same is true of the overlying conformable Lewis shale and 'Laramie' formation."

117. 1910. GARDNER, JAMES H.: The Puerco and Torrejon formations of the Nacimiento group. Jour. Geology, vol. 18, no. 8, pp. 702-741, 3 pls., 8 figs. 1910.

The Tertiary and late Cretaceous formations of the San Juan Basin west of Nacimiento Mountains are described.

The Tertiary beds rest unconformably on the "Laramie," and the Mesaverde coal measures are separated from the "Laramie" by the Lewis shale.

118. 1910. LINDGREN, WALDEMAR; GRATON, LOUIS C., and GORDON, CHARLES H.: The ore deposits of New Mexico.

U. S. Geol. Survey, Prof. Paper 68, 361 pp., 22 pls., 33 figs. 1910.

Brief references are made in many places to the coal-bearing formations of New Mexico.

119. 1911. LEE, WILLIS T.: Further evidence of an unconformity in the so-called Laramie of the Raton coal field, New Mexico. (Abstract.) Bull. Geol. Soc. Am., Vol. 22, p. 717. 1911.

The unconformity separating the coal-bearing rocks of the Raton coal field into a possible pre-Laramie and a post-Laramie formation was traced around the Raton and Trinidad coal field.

120. ——. LEE, WILLIS T.: Correlation of rocks in the isolated coal fields around the southern end of the Rocky Mountains in New Mexico.

(The preliminary announcement of the results contained in this paper was made at the Washington meeting of the Geological Society of America, 1911.)

121. 1912. STOSE, G. W.: The Apishapa folio, Colorado. (In press.) U. S. Geol. Surv., Geol. Atlas U. S. No. 191.

The shale separating the two plates of so-called Dakota sandstone and the lower plate of this sandstone are referred on fossil evidence to Comanche. The upper plate of sandstone is referred to Dakota.

122. 1912. RICHARDSON, G. B.: The Monument Creek group. Bull. Geol. Soc. Am., vol. —, pp. —. 1912. (In press.)

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Dawson arkose is a name applied by this writer to the lower part of rocks formerly called Monument Creek. He states that "it is evident that in the Castle Rock region the Dawson arkose, together with its associated unconformities, represents the time between the Laramie and the Oligocene . . . the lower part of the Dawson arkose seems to pass along the strike into the Arapahoe and Denver formations; that the Dawson and Arapahoe cannot be separated lithologically, even at the type locality of the Arapahoe on the bluffs of Willow Creek; and that the Denver and Dawson apparently merge into each other." It is further stated that "the evidence [of certain vertebrates] implies the correlation of the lower part of the Monument Creek of Hayden [the lower part of the Dawson arkose] and the 'post-Laramie' of the Denver Basin [the Arapahoe and Denver formations]. The evidence of the plants is corroborative, for . . . Doctor Knowlton states that the leaves from the lower part of the Dawson arkose . . . are undoubtedly Denver in age." From these statements it is evident that the Dawson is regarded as Tertiary in age and that the Arapahoe and Denver formations also are Tertiary.

BIOGRAPHY

Willis Thomas Lee was born in Brooklyn, Pennsylvania, December 24, 1864. His early education was obtained in the public schools and in Wyoming Seminary, Kingston, Pennsylvania, which he entered in 1886, remaining four years. In 1890 he entered Wesleyan University, Middletown, Connecticut, and was graduated with the degree of Bachelor of Philosophy in 1894.

During the year 1894–1895 he was instructor in the State College of Rhode Island. For three years, 1895–1898, he was professor of geology and biology in Denver University, Denver, Colorado. In 1898 the degree of Master of Science was conferred on him by Wesleyan University. For two years, 1898–1900, he was a Fellow in geology in Chicago University. During the summer of 1899 he was a member of a geological party led by Dr. S. W. Williston in Wyoming. For a period of six weeks during the summer of 1900 he was engaged as lecturer at the Texas-Colorado Chautauqua, Boulder, Colorado.

For two years, 1900–1902, he was principal of the high school at Trinidad, Colorado. From June, 1902, to March, 1903, he was a student in geology at the Johns Hopkins University. From March, 1902, to the present time, he has been engaged in stratigraphic and economic investigations for the U. S. Geological Survey. During the year 1911–1912 he was again a student in geology at the Johns Hopkins University.

He is a member of the National Geographic Society, Washington Geological Society, Geological Society of America, American Association for the Advancement of Science, and Washington Academy of Sciences.